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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years not more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees	*Annual Dues*
Members	$ 3.00	$ 3.00
Juniors	1.00	3.00
Associates	10.00	25.00
Corporate Members	10.00	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

If Peter Minuit were alive today probably nobody would be more surprised than he at the extent of the bargain he made with the Indians for Manhattan. His $24 investment now has an assessed valuation of more than $7,000,000,000.

But no one should be surprised at the value offered by LOCK JOINT CONCRETE PRESSURE PIPE. For a great many years the low first cost of this pipe has been assured by keen competitive bidding, its simplicity and speed of installation have helped to reduce construction costs, its record for dependable, trouble-free service has been unexcelled and its operational and maintenance costs have been minimal.

What more can you ask in the way of a bargain? Highest quality, low cost, best service, least maintenance—that's LOCK JOINT CONCRETE PRESSURE PIPE.

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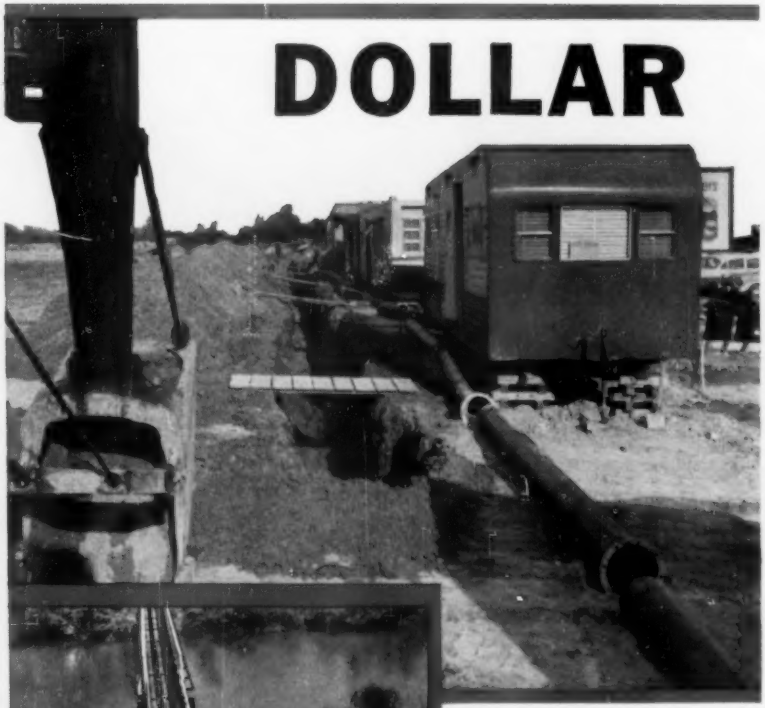
East Orange, New Jersey

Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo. • Perryman, Md.

Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

DOLLAR



Big Business, too, chooses Cast Iron Pipe

Fire protection line for large automotive plant in New Jersey, built with Mechanical Joint Cast Iron Pipe.

Ash disposal line for power plant in Alabama, being constructed with 12" Mechanical Joint Cast Iron Pipe.

MODERNIZED **cast iron**

FOR DOLLAR

Cast Iron Pipe delivers MORE water...LONGER!

Pipe is a capital investment.

But cast iron pipe is an investment that pays off.

- *In longer life* . . . cast iron pipe serves for centuries.
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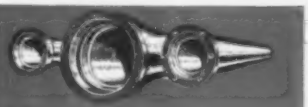
Most important to you, these statements are based on proof, not claims . . . performance, not promise. Specify cast iron pipe, America's most dependable pipe, and be sure, not sorry.

THE MAN WHO CHOOSES
CAST IRON PIPE TODAY
WON'T PAY FOR IT AGAIN
TOMORROW!

CAST IRON

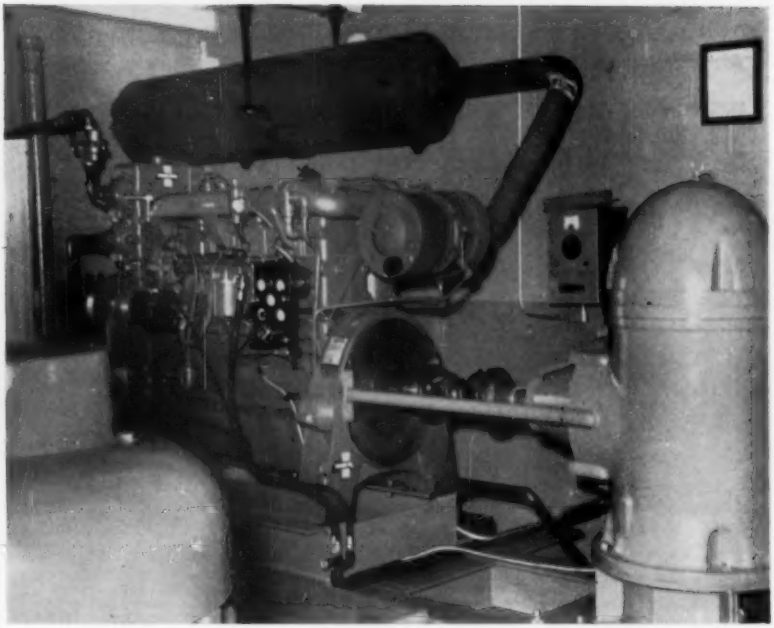
Cast Iron Pipe Research Association
Thos. F. Wolfe, Managing Director
Suite 3440, Prudential Plaza, Chicago 1, Ill.



6 reasons why Cast Iron Pipe is #1 choice of U. S. A.

1. HIGH FLOW CAPACITY . . .
   Cement lined cast iron pipe and fittings will not tuberculate . . . delivers a full flow for the life of the pipe.
2. LONG LIFE . . .
   42 North American cities are still using cast iron water mains laid 100 years and more ago. Hundreds more have passed the 50 year mark.
3. BEAM STRENGTH . . .
   Cast Iron Pipe is inherently tough . . . stands up under heavy traffic load, soil displacement and disturbance.
4. EXTERNAL LOAD RESISTANCE . . .
   6" Class 150 Pipe withstands a crushing load of 17,900 pounds per foot . . . nearly 9 tons.
5. CORROSION RESISTANCE . . .
   Cast Iron Pipe effectively resists corrosion . . . vital factor in its long life and dependability.
6. TIGHT JOINTS . . .
   A full range of leak-proof, low cost, easy-to-assemble joints for pipe and fittings are available for all conditions.

pipe FOR MODERN WATER WORKS



Diesel Engine Driven Pump Unit at Lakeville Pumping Station of Taunton, Massachusetts, Water Supply System

Designed and engineered by Fay, Spofford and Thorndike, Boston, Massachusetts, the new equipment at Lakeville Pumping Station includes a Cummins Model NRTO engine-driven Peerless pump, with a variable speed capacity of eight to ten million gallons per day, as stand-by for an electric motor driven pump of eight millions capacity per day. The new equipment was installed in May of this year.

In July, when lightning struck the station for the second time in four years, the engine was called on to take over on a 16-hour-per-day basis.

CUMMINS DIESEL OF NEW ENGLAND, INC.

201 Cambridge Street
ALLSTON 34, MASSACHUSETTS

205 Lincoln Street
SOUTH PORTLAND, MAINE

720 Union Street
WEST SPRINGFIELD, MASSACHUSETTS

You'll see a demonstration of the completely revolving head. The entire head or nozzle section can be faced in any direction with none of the restrictions imposed by ordinary flanges. All that is necessary is to loosen the bolts in the flange.

We'll be glad to show you the R. D. Wood Swivel Joint Hydrant right in your office

We'll show you the optional breakable flange and stem coupling which permit quick repair and thus give the community better fire protection—and you won't have to get out of your office chair!

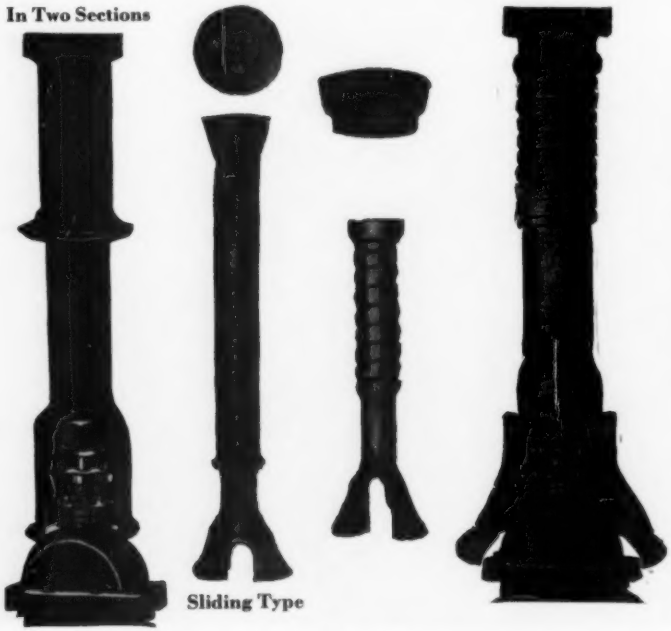
We mean a scale working model, of course, about 2 feet high and accurate down to the last nut and bolt. As we take it apart for you, you will see quite clearly the hydrant's sound, simple construction, the smoothly rounded changes in diameter which reduce friction and deliver water at full pressure.

It's a really reliable hydrant. Like to see it? Write us today for a demonstration.

R. D. WOOD COMPANY

Public Ledger Building, Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves



The Three "Bigs" in Buying

1. *Standardization*
2. *Dependability*
3. *Quick Delivery*

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Genuine Buffalo Cast Iron
Service. Valve. Roadway and Meter Boxes
Manhole Frames and Covers

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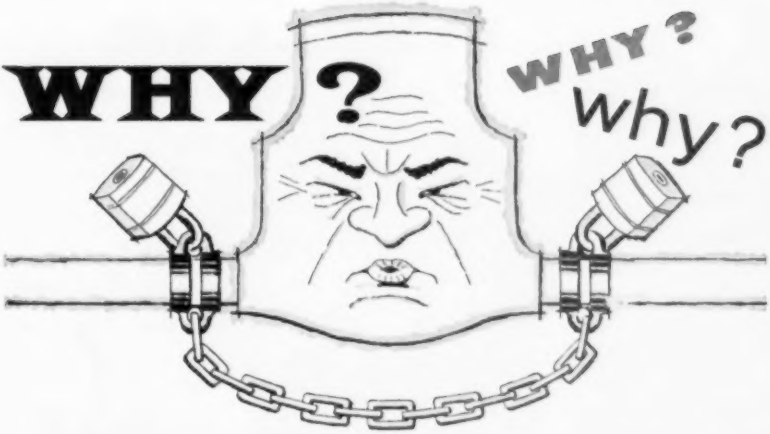
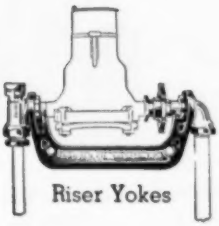


SHACKLE YOUR WATER METERS?



Riser Yokes

Angle Yokes

Straight Line Yokes

Ordinary old-fashioned meter couplings are frequently like shackles on your water meters. They often make meter changing so difficult and troublesome that periodic testing is omitted and proper meter maintenance neglected.

Be sure to set your meters the modern way. See that Ford Yokes are keeping every meter available for fast, fast, FAST changing and testing. Savings in time and increases in revenues can be really substantial.

You can change a meter in a Ford Yoke

EASILY

There are models for every condition. Send for free catalog.

FORD

FOR BETTER WATER SERVICES

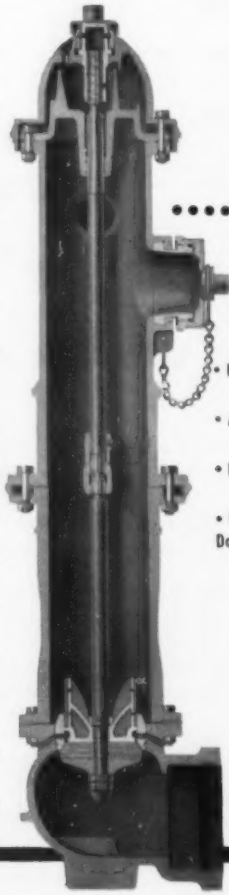
THE FORD METER BOX COMPANY, INC. Wabash, Indiana

Standardize on

MUELLER®

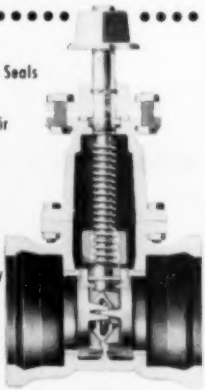
AWWA Fire Hydrants and Gate Valves

- Bronze Weather Cap
- Oil Filler Plug
- Oil Reservoir
- Dry Top Design
- "O" Ring Stem Seals
- Breech-Locked Nozzles
- Individual Non-Kinking Chains
- Safety Stem Coupling
- Concealed Safety Flange
- Compression Type Main Valve
- Double Drain Valves
- Bronze Seat Ring
- Double Drain Openings
- Bronze Cap Nut
- Pedestal Base Shoe



Designed for above-ground maintenance . . .

Mueller AWWA Improved Fire Hydrants



- "O" Ring Stem Seals
- Lubricant Reservoir
- Heavy Bronze Stem
- Acme Stem Threads
- Heavy Cast Iron Body
- Parallel Seat—Double Disc Type
- Bronze Seat and Disc Rings
- Four Point Wedging Mechanism

Designed for minimum maintenance

Mueller AWWA Non-Rising Stem Gate Valves

Ask your Mueller Representative to show you these features on his cutaway models of the Mueller Improved Fire Hydrant and Gate Valve.

MUELLER CO.
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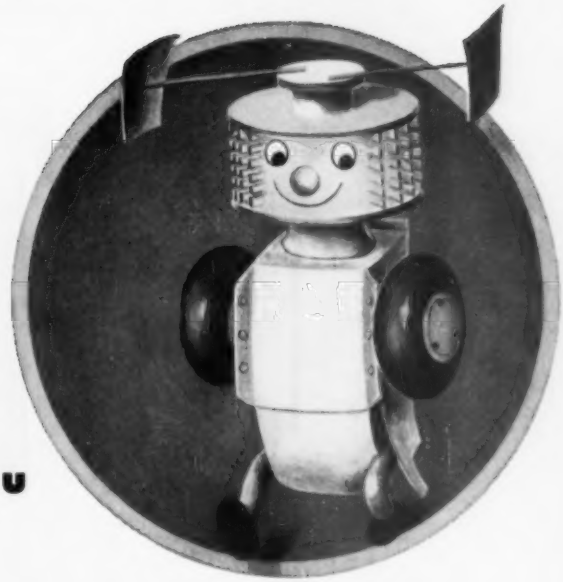
Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario.



have you met

Dr. Centriline . . .

If not, you should! He can do things for you . . . like making your job easier and saving you money. He's a versatile and somewhat ingenious many-armed creature who specializes in cement-mortar lining the inside of pipes. And he's done this to over 4 million feet of pipe, too—eliminating corrosion and tuberculation . . . increasing flow capacity . . . reducing leakage . . . slashing pumping costs . . . and adding years and years of pipe life. If you'd like to learn more about Dr. Centriline and how he can work for you, just write or call for one of our descriptive brochures.

CENTRILINE CORPORATION

A subsidiary of the Raymond Concrete Pile Company

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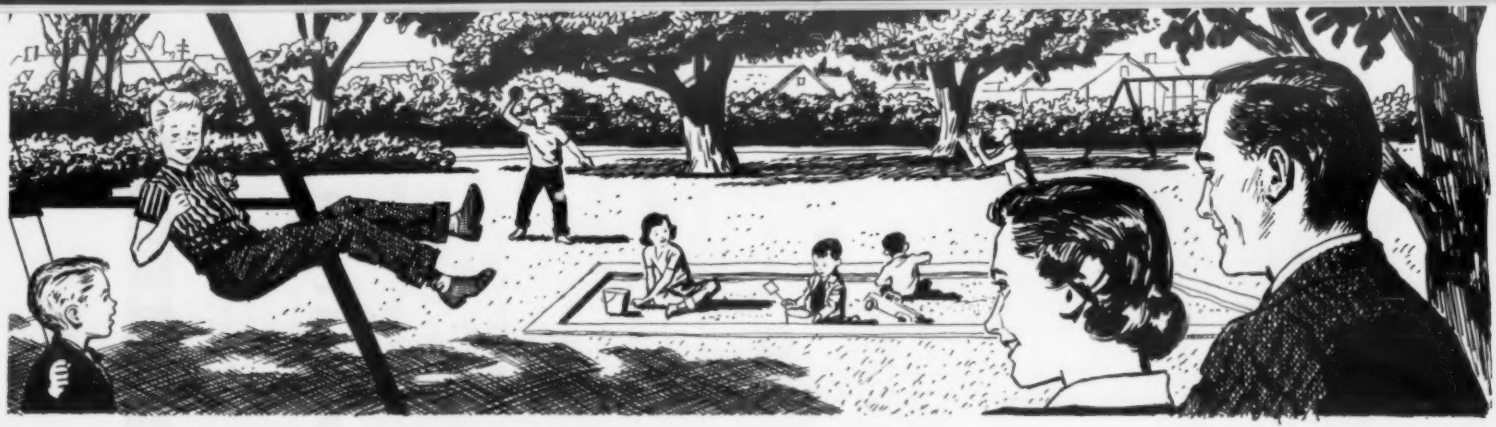
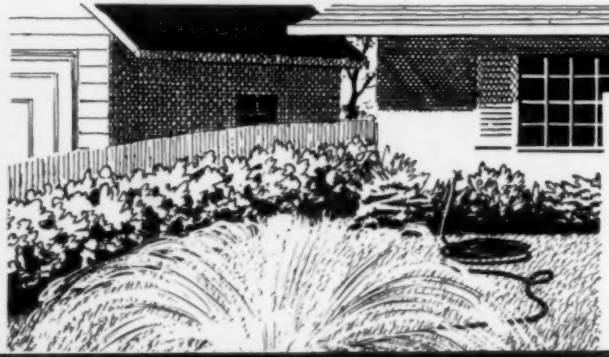
Branch Offices in Principal Cities of the United States, Canada and Latin America

• CEMENT-MORTAR LINING OF PIPES IN PLACE •



Playgrounds assured...

but what about their most precious possession...water?



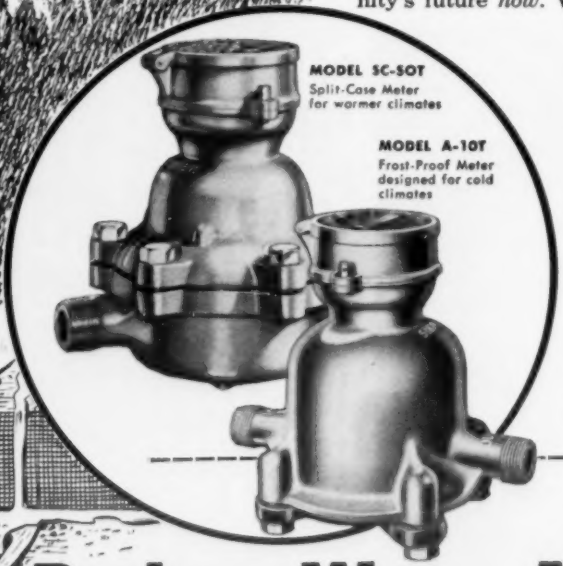
Protect your community's water and future...with Badger Meters

Recreation facilities are an asset to your community. That's why you willingly allocate funds for their expansion. But what about water supplies? They're *vital* to community existence. Yet many communities are retarded in their growth

because there just isn't enough water for expansion.

You can start conserving water and insure your community's future *now*. With Badger Meters, every consumer is assessed fairly for water used or wasted. This fair-share, fair-pay plan stops water waste . . . assures future supplies for community growth. And when water waste stops . . . conservation begins.

Precision-engineered from the finest alloys for lasting, dependable efficiency, Badger Meters put your water system on a profitable business basis. Whether your system requires disc, turbine or compound meters—you can choose the right type from the complete Badger Meter line—in sizes from $\frac{5}{8}$ in. through 12 in. Ask your Badger Meter representative for facts — or write for literature *today*.



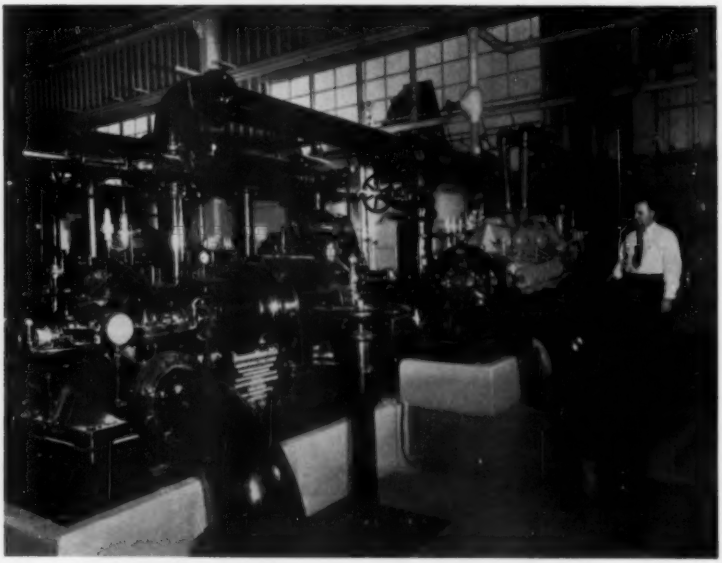
Water is vital

Badger Meters have conserved it better for over 50 years

Badger Water Meters

BADGER METER MFG. CO. • 2371 North 30th Street
Milwaukee 45, Wisconsin • OFFICES IN PRINCIPAL CITIES

ANOTHER FAIRBANKS-MORSE LEADER



Complex fire fighting system guards world's largest Auto Assembly Plant. Ford Motor Company at Mahwah, N. J. Protected by extensive system including two Fairbanks-Morse Centrifugal Fire Pumps.

One of the newest in the Ford chain of 16 assembly plants, the giant Mahwah installation is capable of turning out more than 1,000 cars and trucks in a single two-shift working day.

The system was designed by Ford engineers in collaboration with consulting engineers R. F. Giffels and V. E. Vallet.

The pumps chosen for this important service are two Figure 5814F Fairbanks-Morse horizontal centrifugals. One is a 6-inch pump with rated capacity of 1500 gallons per minute at a discharge pressure of 125 pounds. This is driven directly by a 150 HP Fairbanks-Morse type QZK induction motor at 1770 RPM. The second pump is even larger, an 8-inch F-M unit rated at 2500 GPM and driven through power transfer gears by a pair of 6-cylinder diesel engines. Actually there are three pumps, the third being a 1-inch Figure 5592- F-M centrifugal driven at 3475 RPM by a 15 HP motor.

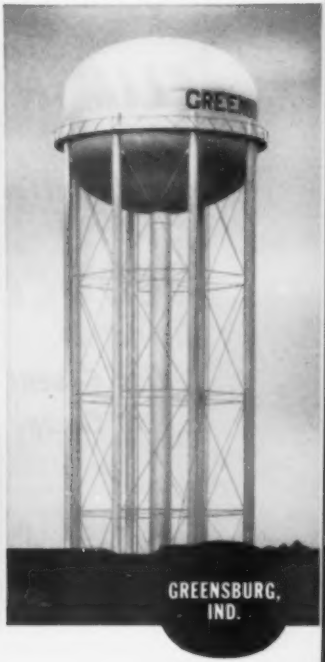
Write or telephone to:

FAIRBANKS, MORSE & CO.

178 Atlantic Avenue **Boston 10, Massachusetts**

Telephone: LAfayette 3-3600

50,000 Gallons | **150,000 Gallons** | **500,000 Gallons**



...the capacities to serve your needs

...top economy and appearance, too!

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ELEVATED
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Pittsburgh-Des Moines' Double Ellipsoidal Elevated Steel Tanks offer an advantageous combination of economical design and pleasing good looks, meeting today's exacting community standards. With very low head ranges in sizes to 300,000 gallons, and good head ranges up to 750,000 gallons, the Double Ellipsoidal tank design covers at low cost the greater part of all municipal water storage requirements. Write for our illustrated brochure detailing the complete range of PDM elevated tank types and capacities.

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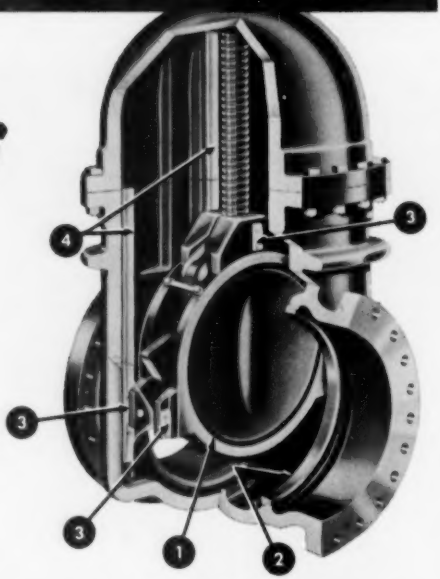
SMITH THROTTLE CONSTRUCTION VALVES

ELIMINATES
disc tilting and chatter

REDUCES
wear of disc & seat ring faces



Smith Square Bottom Throttle Construction Valves have all of the time-proven design and construction refinements of standard Smith Gate and Tapping Valves and are recommended for severe service applications such as throttling in a partly open position, daily or frequent operation against high unbalanced pressure, high velocity or installation in a flat position in vertical piping.

The design features consisting of disc shoes and body tracks mechanically lift and hold the disc ring face (1) out of contact with the seat ring face (2) at all points of disc travel with the exception of the fully closed position.

Throttle construction valve discs are provided with three non-ferrous metal shoes (3), precision-machined and jig located. Valve bodies are provided with three non-ferrous metal machined tracks (4). The three disc shoes register with the three body tracks and each shoe is in contact with a track while the valve is unseated and in any partially open position. The bottom section of each track is bevelled to insure that the shoes will not bear on the tracks when the valve is fully closed.

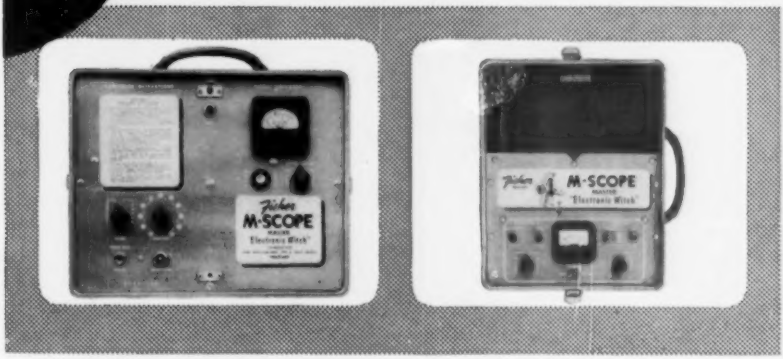
This construction prevents damage to and uneven disc and seat face wear and assures long service life under severe operating conditions.

Single throttle construction is used when the flow is not subject to reversal. Double throttle construction when the flow is subject to reversal.

FIRE HYDRANTS · VALVES · SINCE 1896
THE A.P. SMITH MFG. CO.
EAST ORANGE, NEW JERSEY

New!

TIME-$AVING COMBINATION LEAK DETECTOR-PIPE LOCATOR



THE M-SCOPE MASTER
Electronic Witch Combination

You're looking at the much-talked-about **NEW** M-Scope . . . the only dual-purpose that detects leaks **and** locates pipe. Its rugged, highly efficient electronic circuit, plus ease of use and portability, make this instrument one of the most welcome contributions to the water works industry.

Quick Facts

For greatest convenience and reliability, the M-Scope MASTER is equipped with a **built-in battery tester** for instant checking of battery condition in the field or elsewhere.

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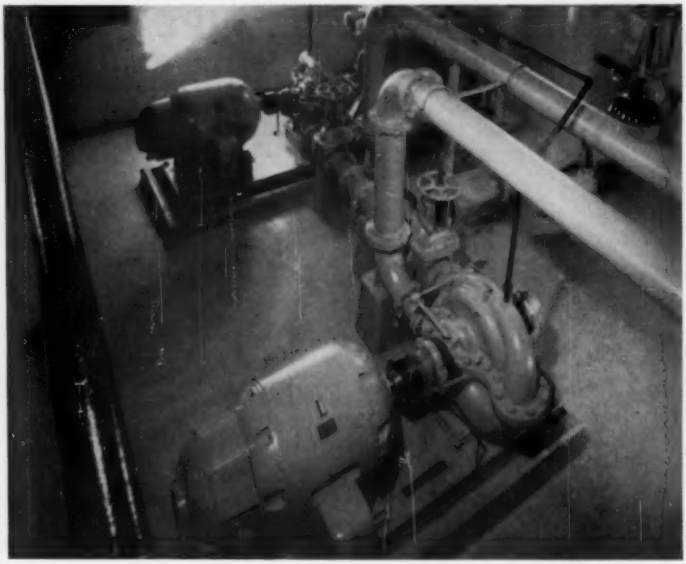

Town of North Andover — New Lake Cochichewich Pumping Station

Pictured above are two De Laval two-stage centrifugal pumping units installed in a modern completely automatic water works station. Design conditions of each unit are 1400 GPM against 280 ft. TDH. Gasoline Engine auxiliary drive is included on one unit for emergency operation.
Our contract included installation of pumps, chemical equipment, intermediate piping and electrical control equipment.
Weston & Sampson, Consulting Engineers, prepared the plans and specifications, and supervised the installation of all equipment.

TURBINE EQUIPMENT COMPANY OF NEW ENGLAND

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New England Representatives for

DE LAVAL STEAM TURBINE COMPANY

TRENTON, NEW JERSEY

LET'S CONSIDER THE **PERFECT** GATE VALVE

Sound design and quality workmanship to guarantee ease of operation, watertight closure, years of trouble-free performance

The perfect gate valve, according to engineers and water superintendents, must combine simplicity and soundness of design, tightness of closure, ease of operation and quality of workmanship.

All Ludlow gate valves and all Rensselaer gate valves are designed to meet these requirements, as well as A.W.W.A. specifications.

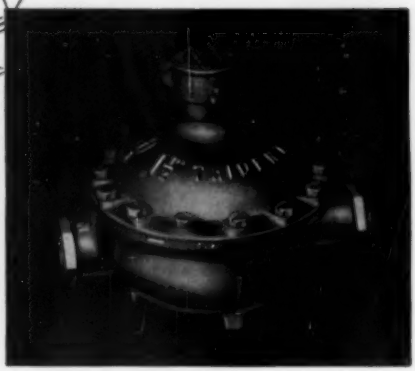
Among the Ludlow and Rensselaer double disc gate valves you'll find the most complete selection of outstanding design features available today. Sizes range from 2" to 72", plus custom design engineering for special applications.

Write today for the L&R Gate Valve Catalogs

LUDLOW & RENSSELAER

VALVES AND HYDRANTS

THE LUDLOW VALVE MANUFACTURING CO., INC., TROY, N. Y.—SINCE 1861



FOR BETTER RESULTS
WITH LESS TROUBLE
...PICK *ONE*
INSTEAD OF TWO

1½" or 2" Style 3 Meter matches performance of complicated compound . . . with less cost and fuss

For 1½" and 2" water service lines, the Trident Style 3 meter is simpler, costs less to buy and maintain, is every bit as accurate, and produces just as much revenue over a wide range of flows as any compound, including our own. Trident was *first* to give you an easy-to-set pressure adjustment. And since modern Style 3 parts fit older meters, there's never any obsolescence.

So why put up with the fuss and expense of *two* measuring units when one Style 3 will do the job? You'll find conclusive evidence in your own records . . . or ask your Neptune man.

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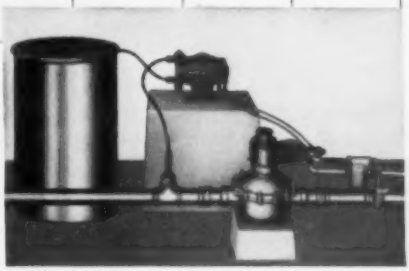

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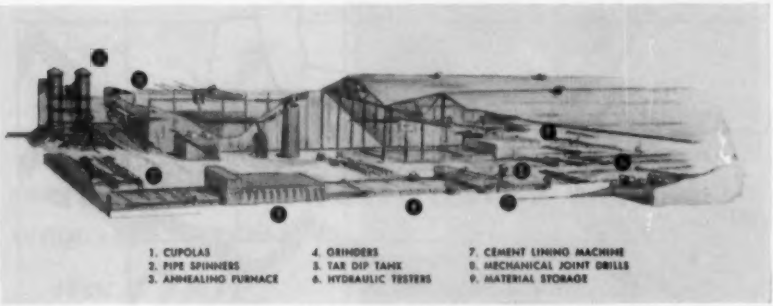

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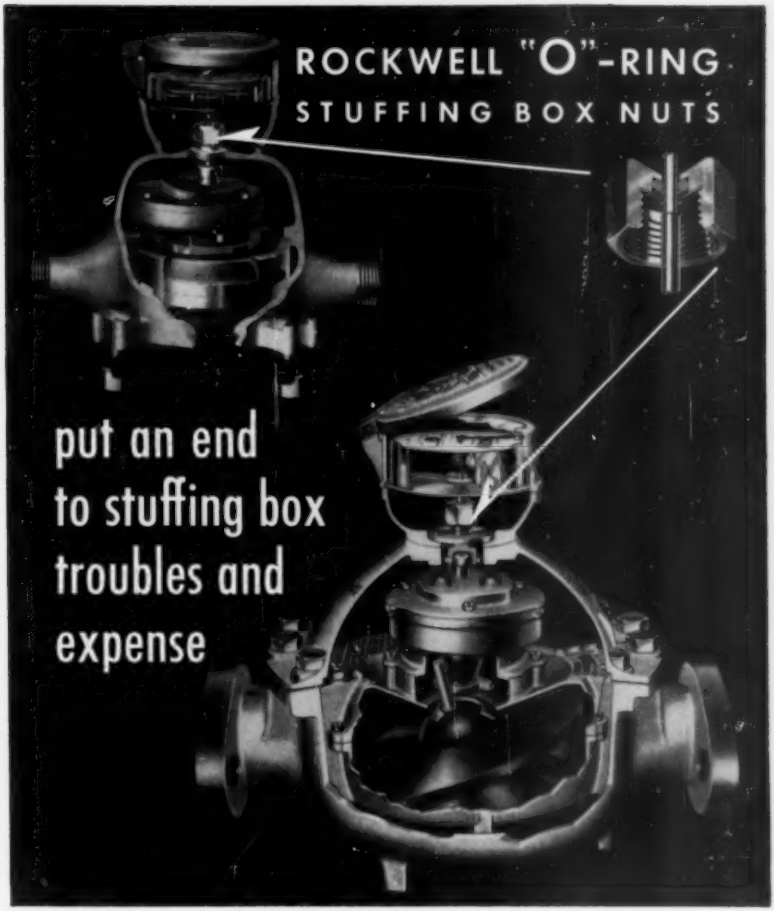

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President of the New England Water Works Association
1957-1958

NEW ENGLAND WATER WORKS ASSOCIATION
ORGANIZED 1882

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MUNICIPAL ADMINISTRATION AND FINANCE

BY EDWARD C. MONAHAN*

[*Presented November 15, 1956.*]

A short time ago the Superintendent of Public Works of the town of Arlington read a paper to you, and apparently it met with some favorable reception. As a result you probably came to the conclusion—logically or illogically, as you will see—that maybe the manager of the community that the superintendent came from might also have something to say about the subject matter. However, I approach this talk with fear and trepidation, because it is easy to generalize on all the problems of a community, but to particularize on such a subject as *water* reminds me of the inability, possibly, of an accountant to deliver a talk to a group of engineers.

However, by way of preface I might say that what I know about water I have learned only because of my experience as a manager. I have been a manager for ten years. Prior to that time I was in the investment business for 20 years. I was later Chief Examiner of the Reconstruction Finance Corp., and in 1947 I became Town Manager of Norwood. Thus I became manager through the financial channel, rather than the engineering channel, which is sometimes more frequently desired, especially in the smaller type of communities.

First, let me say in general that I wish to thank you for this opportunity to come before you and talk to you on the administration of a water department from the standpoint of a manager, which, to be sure, is based upon my own experience in learning the business in a relatively short time of ten years, when many of you men have devoted your entire life to it.

To set the stage for my observations, which may in many cases seem repetitious to you, it would seem important that I

*Town Manager, Arlington, Mass.

say that Arlington is a community of 47,000 people by the Federal census of two years ago. Our total consumption of water per year is in excess of 1.2 bil gal. Our source of supply is the Metropolitan District Commission. I give that preface in order to explain what our problem might be in respect to population.

Norwood

When I became manager of Norwood, which is a community 15 miles south of Boston, the problem there was that we appeared to have an inadequate supply from natural sources, considering the fine future that Norwood had industrially. Our average production per day was 2 mil gal. That came from a combination of driven wells and one gravel-packed well, and a pond by the name of Buckmaster Pond in Westwood.

If you will recall, in 1947-48 there was a very serious drought, and it became rather important to the town of Norwood to find new sources of water. We were very fortunate by experimentation to find a well underneath the bottom of Buckmaster Pond that by qualified engineering estimates would deliver 1.5 mgd under drought conditions.

However, even that was not sufficient for the long-term desires of the people of Norwood, and since that time, under the guidance of one who had been a member of this Association for many years—Jack Kennedy, who succeeded me as manager, and who was formerly in the water department of Winthrop—steps were taken for Norwood to become a member of the MDC system, which was inaugurated within the last two weeks.

Revere

Then I went to Revere as city manager, and I was there for three years in that very interesting but very exciting city—that is how Professor Landry of Harvard refers to it. In Revere we already had the MDC water system. However, the distribution system of the MDC had not quite overcome the handicaps of delivering water to the higher spots in Revere, so that it became necessary, during periods of peak demand, to send the fire apparatus down to the bottom of Reservoir Ave. and Broadway, to pump water into the system at the top of the hill for people to have sufficient water to flush their toilets.

I know the MDC had been planning and is still continuing to plan to improve the distribution system in respect to Revere, but Saugus is also involved in the problem, and it may take some little time more for Revere to be accommodated completely and adequately in connection with the water that it needs during periods of peak demand in July and the latter part of June.

Arlington

When I went to Arlington as Manager in 1953, I felt that I had nothing to worry about in regard to water, because we were connected with the MDC, and we had reservoirs on two hills in excess of 300 ft above sea level, the rest of the town being in a valley. I thought I could concern myself with other problems and forget water. Unfortunately, two years ago we had a fire in Arlington in one of our schools, and it became quite evident, as a result of the inadequacy of water to kill the fire at the school, that something was wrong with the water system in the town of Arlington.

At the time of this fire, we had a 6-inch main on Oxford Street. We dug up that main and it was completely tuberculated; it did not have the volume of a 3-inch pipe.

The situation was precarious, I felt, and as a result a committee, headed by our present Superintendent of Public Works, Mr. O'Hara, and our present Fire Chief, who was then Deputy, made a survey of the town, and I think that has probably been explained to you by Mr. O'Hara in the paper he read several weeks ago.* But the fact of the matter is that their survey showed street after street of mains that were considered bad. A total of 60,000 ft of mains was in the category of poor to bad.

As a result, the Town Meeting appropriated $40,000 on the basis of a five-year plan to spend $200,000, which is the estimated cost of restoring the Arlington water system to a condition that we can consider satisfactory.

We are now in the process of cleaning mains. Last year we cleaned seven or eight miles; this year we have already cleaned three or four miles of main. We have also made extensions of the system, to eliminate dead ends and improve circulation.

From time immemorial it has been the practice of some com-

*This Journal, 71:3, 188, Sept., 1957.

munities to have a public works department, or the water department, if you will, take care of the hydrant system. We feel in Arlington that that just is not the right thing to do. We think that the job in the first place should be done by the members of the fire department. We feel that errors in the hydrant system or the water system should be brought immediately to the attention of the Water Department, who will take prompt action to correct it.

There have been up to the present two schools of thought, with some feeling—including Percy Charnock of the Fire Underwriters—that it is the job of the Public Works or the Water Department. However, we feel, as I say, to the contrary, because it is our thought that the Water Department has a lot to do, and it would be very helpful to the community as a whole if the firemen became a little bit adjusted and obtained a little knowledge of water. After all, what good is a piece of fire apparatus if the man driving it does not know what hydrant to tie into or if he ties into the wrong hydrant when, if he had a knowledge of the system, he would not make that fatal mistake?

We believe it is important in the in-service training of firemen that they know water, know pressures, know, in fact, hydraulics in the higher echelons of the Department.

With the type of in-service training that our men get—it may be said that this year every single hydrant in the town of Arlington has been tested by members of the Fire Department—we bring the pressures right out. We not only test the static pressure of the hydrant and the flow, but tie in on the basis of how many gallons per minute will be needed to take care of this particular area. We open up several hydrants at the same time.

The city of Boston has very recently—when the present Chief of the Boston Fire Department was a Deputy—inaugurated such a system, and when you see the fire apparatus beside a hydrant and no fire, you know what they are doing. They are simply testing their pressures from a fire standpoint. That is usually done at night. We do ours from ten o'clock at night to twelve or later.

Troubles of a Manager

Those of you who live in Massachusetts especially are probably interested, in an abstract manner at least, in the appoint-

ment of a Manager. You know there are some people who say that a Manager should live hazardously, at the will of the Council or Board of Selectmen; there are others who say he should be appointed for a fixed term; others say he should have tenure.

In my particular case, I have lived under both of those systems—that is, the fixed term and living hazardously—and I recently sent a paper to the University of Michigan, which was making some inquiries about the business managers and in respect to their offices. It is my thought now, as it has always been, and I have so expressed myself to the committee, that a Manager should be appointed for a definite term initially and thereafter left at the will of the Selectmen. If a Manager is appointed for three years, there is no point in having him reappointed again for another three years. Let him live hazardously, because if by that time he has not proven his worth, he is of no value to anybody anyway, and if by that time he has proven his worth, the general public will appreciate his abilities and a political body would hesitate to move against him.

But you can see what a difficult time it is for a Manager whose term is expiring, and who still has to supply bread to the table, when extreme political pressure is brought upon him as his first term closes, with the implied threat that he might not be reappointed. It would be better that no action be taken on his appointment at the expiration of his first fixed term; let him live hazardously and at the will of the elected body.

Administration of Water Department

Now, I think we will all agree—especially those of us in public water departments—that a water department at one time was more or less self-sustaining from the standpoint of receipts and expenditures. It is a moot question today whether or not many water departments of cities and towns are on a paying basis, if we consider all of the cost factors which enter into our running of a department, both direct and indirect, including fringe benefits. It remains to be seen how much longer water departments in cities and towns can operate on the black side of the ledger, because, as we all know, there is a serious question as to whether the present charges for MDC water of $80 per mil gal are realistic or not, in consideration of their own costs, and

there might very well be an increase in those rates—some of us look forward to it. I am speaking of those systems that are tied in directly to the MDC.

Meter Reading

Naturally the water department is very important to the community. It is the big source of revenue to the community—we at least do get something back from our water departments. This brings me to the question of meter reading. I have often wondered whether there is a feeling among, at least, public water men, that our meter readers are abused if they have any more than 50 or 60 meters a day to read. I have run into that. It seems to me as though the books that are used for meter reading just work themselves in very nicely to a planned slow-down in respect to meter reading.

We have on the average 87 readings a day in the town of Arlington, which is an improvement over what it was. But I think that water men—men at the top level—should concern themselves with increasing the production of the meter readers. Surely you fellows work a full day and week-ends, and it certainly is no injustice to expect a meter reader to work a full day.

Some time ago I had a young college fellow who worked in the summer time, and I asked him later, after he got through, to tell me just about what time he got through every day. It is a fair statement that he was young, youthful and energetic, and maybe he was anxious to play baseball in the afternoon, but the fact of the matter is that his production was as great, and I presume as well done, as those who were officially employed in the department on a permanent basis, and there never was a day when he was not at home, in his house, by two o'clock. When I went to Revere I had a fellow who was teaching golf in the afternoon in the Revere High School.

Meter reading and the promptness of billings mean so much to a city or town. After all, your whole tax structure is set up on the basis of how much money will come in, and if you don't get your bills out you don't have that money coming in, and that causes the excess and deficiency fund to be drawn upon to alleviate the tax rate the following year. So that it is very important that we have more meter readings and that we have

prompt billings, and that we also have, coincident with those, an alertness in collections.

Now, it is almost needless to say that we definitely should watch very carefully the elimination of old meters because, as we know, an old meter is a source of declining income to the community, even though people who have old meters sometimes do not realize that when they ask you to change them.

Foremen

Now, we recently had an examination for foreman, in the Public Works Department, to be sure, but we had intended using him in the Water Department. Now, I just don't know what has happened to those who make up the Civil Service examinations, as the two top men on our eligibility list were men who had never worked in the Water Department of the Public Works Department. Fancy that! To be sure, the Public Works Department in Arlington is an integrated unit. We transfer men from one department to another. We have the same difficulties as other communities have with the fellow who knows all of it from the practical standpoint but can't put it on paper. But here was a case where two men who topped the list for Public Works Department had never worked in the Water Department, even though the Civil Service requirements and the duty classification called for knowledge in every phase of water. I think that the office of foreman somehow or other has been derogated in the past years.

We have reached the stage in many municipalities where foremen, as far as dollars are concerned, are hardly any better off than a Grade 3 operator, a few dollars separating them. To me a foreman is a big guy. He is on the management side of the table; he is supposed to accept full responsibility, and in order to get the men to do that and follow through on it, it seems to me that we have to revise our thinking in respect to foremen in the municipalities and put them at least five or six grades ahead of other men in the department, so that they will have a dignity to go with it—so that they will be able to take up their full responsibility fearlessly and see that the men are working the full time for which they are being paid. I would suggest that all of us in municipalities give serious thought to that and not be

bewitched by the blanket type of increase. Let us separate them. Let us put a foreman up there some place, and then let us give him an opportunity to train for even greater responsibilities.

Training Personnel

I think that we have a responsibility ourselves to train men in our department. Let us not assume too much about the young fellows that we are picking up today under the Civil Service eligibility, which means nothing more or less than a fellow's chronologically putting his name on the list and making crosses against his name.

The old-timers remember when the young fellows came out of grammar school and had a pretty good knowledge of fundamental arithmetic. They certainly do not have it today. There may be exceptions, of course, but the rank and file do not know arithmetic. You can confuse almost any one of them on fractions and percentage. I know. I have six children, and I know what they didn't know about arithmetic as they were coming along, and even when they got into college. So let us not assume too much about these fellows who work for us. They have to be trained and we have to train them. Not to train these employees is a serious disservice to the community.

When I went to Norwood I heard stories about the old Superintendent of Water. Whenever they wanted to locate a service or a main, he would get out of bed in the middle of the night and take three steps to the left and four to the right, and there it was. As a matter of fact, Frank O'Hara's father was a genius at that; in other words, he knew where every installation was in the town. However, it is pretty serious for those who follow if we do not have our circulation system, our distribution system and our services pretty well marked out by our engineering department.

Public Officials

Now the next step I should like to talk about is the problems of all of us. I have confined myself to knowledge of water, and those of you who are in private water companies will have to bear with me. I know nothing about the problems of the private water companies, so that I have to talk about what I know about

—water as a public official. It would help tremendously if elected officials would try to understand our problems.

Public officials generally may be so wrapped up in their telephone calls, demands of pressure groups and all that sort of thing that they make no serious effort to understand the problems of the municipalities. That would be particularly true of the Water Department. I had a criticism this last week. We were cleaning mains, and I was asked, "Why do we have to keep these trenches open so long; why can't we do it and finish it up?" In other words, we were supposed to go in in the afternoon, dig out the trench, and clean the pipe immediately, and he was offended because the lanterns were outside on the street.

I do think that we should make some effort to encourage our public officials, our elected officials, to try and understand the problems that we face in our work every day and every week.

I do think, too, that we need better public relations. I think it is important. So many of us work every day, and we think that the results will speak for themselves. I shall give an example: In our town report we have a report of the activities of the Water Department, broken down into every phase of it. There are ten pages, covering every conceivable kind and nature of work done. I should like to know the number of local public officials, elected officials, who have read that. We assume that they know. They do not know. It is important to us to inform the public by good public relations, good press relations, as to what we are doing, how big is our job, how long it takes to accomplish it, what are the problems involved, and all allied questions.

Taxation and Public Relations

Now, gentlemen, as I near my close I should like to say a couple of things here. There is not any question that we are all facing the crushing burden of taxation pursuant to the increase in the school population. In Arlington alone in the last three years we have put an addition onto the Fisher School and an addition onto the Palmer; we have built a new 17-room school and a new 22-room school, and now a $2,000,000 addition to our High School. We have not yet taken up the full load of debt and interest, nor have we taken up the full load of operating expenses.

During this period of tremendously high taxes, which are almost confiscatory from the standpoint of the small home owner, especially the widow or the person living on a small income—all of us being conscious of the terrific cost of schools—I think that we have a chance this year to build upon the normal increases that we need in our own departments. We have long made way for this tremendous capital outlay for schools, and we shall continue to in connection with operational costs. We must face, gentlemen, the possibility at some time very soon of really serious increases in pay rates for the teachers. That definitely is coming, because, by any standard they are underpaid for the caliber of education and experience they have. The schools have no trouble whatsoever in bringing home to the public the reasonableness of their requests.

A woman got up in our town meeting one night and said, "When you take down the barriers from a newly-constructed street, deterioration and depreciation begin; when you take down the barriers of a reconstructed school, our increment in our citizens' future begins." Right after that the appropriation came up for the School Department, and the Moderator said, "Speak up so that I can hear you; $2,000,000 on this high school. All those in favor say 'Yes'."

The Chairman of the Building Committee, who had prepared himself for six weeks to answer questions, was asked one question: "Who prepared the brochure on this school, and from what source did it come, the payment for it?" He was not asked a single other question. That was the result of good public relations. The School Department had completely impressed upon the town-meeting members that it was definitely needed.

We have in some way to bring to the public the tremendous importance of our work. And along those lines, gentlemen, do not overlook the possibility of making developers pay completely for all their installations. Up to a few years ago the town of Arlington practically gave the town away to the developers. In the last three years we have been able to reduce the cost of our water extensions and sewer extensions $100,000 a year, by insisting that the developers put in the water, the sewers, the black-top streets and the sidewalks, and they do it. Many a town is going to go broke by borrowing money, following the rainbow

and the mirage. It is wonderful to have new buildings—it helps the town. They can pay their way. We do insist upon it.

Conclusion

In closing, I should like to say that you men are leading this very vital public service, and you must set up the standards; you must inculcate in your men some comprehension of dedication to their work, in their own personal interests and in the interests of the community as a whole for whom they work.

ENGINEERING AND DESIGN PROBLEMS IN CONNECTION WITH CONTROLLED-ACCESS-HIGHWAY UTILITY RELOCATIONS

BY KENNETH E. BENDER*

[*Read April 18, 1957.*]

The United States has started building the greatest network of roads ever conceived by man. By 1971, there will exist some fifty billion dollar's worth of roads, most of which are not on the road maps of today. When finished, the project will affect directly more Americans than anything our nation has ever built. If you own a car—if you take an hour driving 15 miles to work—if you have spent an otherwise pleasant Sunday afternoon creeping through one bottleneck after another—if you have ever been in an automobile accident—you are directly affected!

Each year, it has become more obvious that the country—the most mobile nation on earth—is being strangled by poor roads. In 1956, there were 65,000,000 vehicles on the road. By 1975, this figure is expected to be well over 90,000,000.

At the conclusion of World War II, industry began to divert its efforts to the production of civilian material, and as the finished products began rolling off the assembly lines, the transportation systems started bogging down. Along with increased industrial activity, there began a general shift in population from the cities to the suburbs and, of course, the creation of many two-car families.

The New England area, and in particular Connecticut, where population density is quite high and industry plentiful, soon felt the effects of inadequate and obsolete roads. To rectify the situation, the State of Connecticut in the early 1950's started developing plans for a super-highway to traverse the length of the State. This highway was designed to relieve the congested conditions, provide a good link between the metropolitan areas of New York and Boston, and provide an economic booster.

The 129-mile route, extending from the New York line to

*Superintendent of Distribution, Bridgeport Hydraulic Co., Bridgeport, Conn.

the State line of Rhode Island, will pass through 28 towns and cities. Many residences, as well as commercial and industrial establishments, will be forced to relocate. The Turnpike was divided into thirty administrative sections, and each section was under the jurisdiction of a consulting engineering firm, which handled all of the complex problems within its division, ranging from the layout of the right-of-way to details of construction of the 198 bridges throughout the length of the Turnpike. Needless to say, these engineering firms are all experts in the field of highway design; however, when it comes to the relocation of utilities, they are not too well prepared to cope with the minute details that are required. Naturally, it is quite human for each individual to over-emphasize the importance of his own utility problems and, therefore, it is not too surprising that quite often differences of opinion arise between the highway engineer and the utility engineers.

In December of 1954, the Bridgeport Hydraulic Co. was first contacted by the State Highway Department, regarding its plan for the construction of the Connecticut Turnpike. Examination of the hundreds of plans soon revealed that we were faced with a staggering job and we, therefore, deemed it necessary to set up a separate Turnpike Division.

The Bridgeport Hydraulic Co. was most fortunate, in that a complete engineering study had been made of the distribution system during 1953 and 1954. This engineering study provided a valuable aid to the men in the Turnpike Division, as they knew which lines could be taken out of service and what the result would be to the system. Had this information not been available, it would have taken considerably longer to complete the field work and, no doubt, we would have had considerable problems with low pressure and "no-water" calls.

Our experience here in Bridgeport is more or less typical of the extent to which the construction of a major highway affects the city utilities. After careful examination of the plans presented by the Highway Department, it was determined that we had 319 jobs to do in regard to the Turnpike. These included the laying of some 42,000 ft of pipe and abandoning approximately the same quantity of pipe. Additional work required was the relocating of some 65 fire hydrants and approximately 80 jobs of

raising or lowering water mains, to provide the proper grade line for Turnpike drainage lines.

This utility required approximately one year, using the services of three engineers, to plan the relocations, plan the drawings of all the work to be accomplished, make detailed estimates, and compile a listing of materials, such as valves, fittings, pipe, etc. The total estimated cost was expected to be $680,000.00.

Actual field construction was started in March, 1956, and all of the relocations were done with our own personnel and equipment. It was the feeling of this company that since the work was so meticulous and since the heavily industrialized and populated areas of the city were going to be involved, it would be far better to use our own forces rather than contract for the work. Many of our supervisors were kept fully occupied and on the job seven days a week.

In preparing our engineering design, we kept constantly in the back of our minds two principles: (1) that we would not do any relocation work that would prove detrimental to the distribution system; (2) that we would relocate no mains directly under the Turnpike fill.

Most of us in water works will readily agree to pipeline relocation, if reasonable provision is made for maintenance, and if we are paid for it; however, a water main buried under a 20- to 30-foot highway fill becomes a serious and costly maintenance problem. As most of you can appreciate, if an 8-in. or a 12-in. main should burst under the Thruway fill, the high rate of flow would probably wash the fill away in a matter of minutes rather than hours. The resulting damage to the Thruway would probably require that at least one or two lanes of the Thruway be closed to traffic. Not only would this create a real hazard on a highspeed highway, but it would be exceedingly costly. The occurrence of a leak or break such as this would require expensive excavation work and sheeting, and the repair might require several days. If the main in question happened to be one of the principal feeder mains to an area, the outage of service might very well be extremely serious, from both a domestic and a fire-fighting point of view.

All of our designs were conducted with the thought in mind that we would cross the Turnpike only by either suspending

our main from a bridge or going through an underpass. We were able to accomplish this in all cases with one exception.

The one exception that I have referred to occurred in Westport. Since there was no bridge to use nor an underpass, we asked the State to provide a pipeline tunnel. At first the Highway Department was severely opposed to any such arrangement, but, after reviewing the problem with them, we arrived at an equitable solution, and it was decided to incorporate a pipeline tunnel along with some of the drainage facilities for the Turnpike. By increasing the size of the proposed culvert and changing its location slightly, we were able both to utilize this facility and to achieve our purpose. This is the only point at which we have a main crossing under the Turnpike.

It was mentioned above that a complete engineering study of our system had been conducted, and this made it quite possible for us to determine which lines could be taken out of service and what the effect would be on our system. This same survey proved to be of tremendous value to us when considering what improvements we might make at the same time that this relocation work was being conducted. By having all the facts available, such as consumption, rates of flow, velocities, and pipeline coefficients, we could plan intelligently any betterments that we wanted to include at the time of doing the Turnpike work. The importance of having complete engineering data available at all times on the operation of the distribution system cannot be stressed too much. Many superintendents and engineers in the field of water works often take the view that most of the conditions in the system remain static. However, this is not the case. In the last ten years, many cities have experienced considerable growth, particularly in the outlying suburban areas. This, of course, has overtaxed the existing water system. We have had to face this problem squarely here in Bridgeport, and every dollar invested in engineering services was well spent, as we were able to handle all of our relocation work intelligently and efficiently.

Aside from the vast amount of work we had to do with our facilities in the field, we were also confronted with the fact that the block-square property housing our Construction and Service Department, situated in downtown Bridgeport, lay directly in the path of the Turnpike.

During the summer of 1955, the Hydraulic Co. began making plans for the construction of a new Construction and Service Department plant. In the spring of 1956, when all plans were completed, ground was finally broken for the erection of this plant at Bostwick ave. We have indeed had several busy years, not only in relocating our distribution system, but also in picking up our Construction and Service Department and moving to a new location.

It is hoped that this brief discussion will be of some value to those who will have to face similar problems in the next few years. We in the water-works field are as interested in doing a good job in our field as the highway engineers are in theirs. Pipeline relocation requires specialized engineering ability, and the water-consuming public, as well as the traveling public, is equally deserving of consideration.

PORTSMOUTH AIR FORCE BASE WATER SYSTEM

BY PAUL F. HOWARD*

[*Read May 16, 1957.*]

In order to build the Portsmouth Air Force Base where it is now located on the Newington Moraine, it became necessary to demolish two of the city of Portsmouth water supply plants known as the Haven Station and the Goslin Station. The water supply at the Haven Station was secured from four 8-inch wells about 60 ft deep and was pumped by means of an electric motor-driven centrifugal pump, with the usual priming system, into the Portsmouth distribution system. The water supply at the Goslin Station was obtained from fifty 2-½-inch driven wells about 53 ft deep and was also pumped into the distribution system by means of an electric motor-driven centrifugal pump. The Goslin Station was located about one-half mile northeast of the Haven Pumping Station.

The Newington Moraine is about three miles long and one mile wide, with the long axis lying in a northwest, southeast direction. The Haven Wells were located about in the middle of this moraine and one mile east of Great Bay. The normal water level in the moraine is about 55 ft above sea level.

The water levels observed in observation wells between the two pumping stations indicated that the pumping from one station did not affect the pumping from the other station. During the years 1948-1950 the pumpage from these supplies averaged about 800,000 gal per day.

The paving for runways, aprons, roads, parking areas, etc., situated on the moraine will cover an area of about one square mile. It was recognized that this would prevent much of the precipitation from percolating into the ground, as it would be diverted by means of drain pipes and ditches, the largest drain being nine feet in diameter. In order to judge better how much water would be available to a well, located in the vicinity of the Haven Pumping Station, a seismographic survey was made by

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the Soils Division of the U. S. Corps of Engineers. This survey covered most of the area of the moraine. Contours of the ledge surface were plotted, to determine the extent of the underground water-bearing formation that comprised the aquifer. It was interesting to note that the wells at the Haven Pumping Station were located in the area where the ledge was at the lowest elevation, and were thus placed in the greatest depth of water-bearing formation. The survey also showed that the ledge rose up rather close to the surface in a ridge between the Haven Pumping Station and the Goslin Pumping Station, which confirmed the experience of the city that the two water supplies did not affect each other.

A gravel-developed well with 24-inch casing and slightly smaller Everdur metal screen, 15 ft long, was built between the runway and the large parking apron, close to the location of the original Haven Wells. Since no building could be constructed in this area above the ground, a submersible type, electric motor-driven, deep-well turbine pump was installed in the well and a concrete vault built over it, with the entrance flush with the ground. Controls were remotely located in a building constructed above the ground, adjacent to other buildings. This pump has a capacity of about 700 gal per min to assist in meeting peak demands. The capacity of this well is limited by the percolation of the precipitation into the ground, rather than by the capacity of the aquifer to furnish the water.

Extensive test-well investigations were made in Portsmouth, Newington and Greenland, which indicated that the soil formation was such that a satisfactory additional water supply, to replace the supplies which had been demolished, could not be obtained in these areas. Since this Portsmouth area is a peninsula, bounded by tidal waters, it was not possible to obtain the additional required water east of Great Bay.

It was decided to investigate the extensive gravel areas north and west of Great Bay, in an effort to determine the groundwater potential of this large area. Several areas were located by means of test wells, which indicated that a substantial supply of ground water could be obtained in Madbury, Dover, Barrington and Lee. As a result of these investigations the area in Madbury nearest the base was chosen to be developed first by means of

gravel-packed wells. The remaining areas in which water was found were eyed by the municipalities in which they were located, and they expressed objection to their being developed for the Air Base and Portsmouth supplies. The Madbury supply was developed by means of four gravel-packed wells with electric motor-driven turbine pumps and standby gasoline engines. Consideration was given to developing a large surface supply to serve the Air Base, the city of Portsmouth and other municipalities, by building a dam and reservoir on the Isinglass River in the city of Rochester, near the Dover line, and filtering the water. Such a development would have been beyond the scope of the project and was ruled out by the Air Force.

During the first year's operation, commencing February 3, 1956, 440,355,850 gal were obtained from the Madbury supply, or a daily average of about 1.2 mil gal.

The yield of the wells has been disappointing. The reason for this insufficient yield is in no way due to the design and construction of the wells themselves, but to the water-bearing aquifer. The conventional and commonly accepted methods of testing the area were used, but the disappointing yield seems to show that there exists a subsurface cut-off that affects the transmissiveness and storage characteristics of the aquifer.

The water from Madbury is conveyed into the Portsmouth distribution system by means of five miles of 24-inch main from Madbury to the Foxpoint Road Booster Station, with the exception of two 20-inch subaqueous pipelines, each about one-half mile long, crossing Little Bay. The 24-inch pipe was Lock-Joint Pipe, and the two 20-inch subaqueous pipelines across Little Bay were Molox pipe, 250-lb class. This Molox pipe has a ball-and-socket joint, and each joint was bolted together with 24 bronze bolts. This type of joint was very flexible and enabled the contractor to install the pipe by means of a chute, hinged from the back of a barge. The two 20-inch pipes were laid in trenches dug in the bottom of the bay, so as to have two feet of earth cover. Divers were used to inspect the trench before the pipe was laid and also to check the backfill operation. Periodically the pipelines were tested by means of air pressure, in order that any leaks might be detected by air bubbles before the trench was backfilled.

Studies showed that the cost of two 20-inch pipelines under Little Bay would be much less than the cost of a single tunnel. One 20-inch pipeline for this short length has sufficient capacity to meet the requirements.

Since there was to be a single 24-inch pipeline, with the exception of the Little Bay crossing from the source of supply in Madbury to Foxpoint Road Booster Pumping Station, a 1.5-mil gal storage tank was built to supplement the supply in case of a break on the single 24-inch line. This 1.5-mil gal tank is a ground-storage steel reservoir, located at the rear of the Foxpoint Road Booster Pumping Station, near the junction of Foxpoint Road and Route 16, or the so-called Spaulding Turnpike just north of the entrance to the Portsmouth Air Force Base. From this reservoir and Booster Pumping Station a 20-inch Lock-Joint pipe was laid, connecting to the Portsmouth distribution system at the 16-inch main in Islington St., located between two of Portsmouth's three storage facilities—namely, the 528,000-gal standpipe and the 500,000-gal elevated tank. The total capacity of Portsmouth storage facilities, including the 250,000-gal Wentworth Acres elevated tank, is 1,278,000 gal. The ultimate plan for the Air Base Water System includes an additional ground-storage reservoir of 1-mil gal capacity to be located adjacent to the present 1.5-mil gal reservoir. Under normal operations the water is pumped from Madbury directly into the Portsmouth distribution system. The overflow elevation of the Portsmouth storage facilities is 172 ft above sea level, and the pumps are capable of pumping water to this elevation. The overflow elevation of the ground-storage reservoir at Foxpoint Road is 127. It is not intended that this ground-storage reservoir float on the line; instead, it is to be used during peak consumption periods and in cases of emergency.

The storage requirements of the Portsmouth Air Force Base were met by the construction of two 400,000-gal elevated tanks and, in order to meet the requirements of the Air Force as to pressures within the Base, these elevated tanks have an overflow elevation of 230 ft above sea level. Therefore, the Base becomes a separate system and has to be supplied by means of boosting the water from the Portsmouth System into the Base. This is carried out by electric-motor-driven, centrifugal booster pumps,

located in the Foxpoint Road Booster Pumping Station. In this station are two electric-motor-driven centrifugal pumps for the Air Base, one gasoline-engine-driven centrifugal pump to be used to pump water into the Air Base in the event of power failure, and two electric-motor-driven centrifugal pumps capable of boosting water from the ground-storage reservoir into the Portsmouth System, together with a gasoline-engine-driven centrifugal pump to be used in case of power failure in the Portsmouth electric units. The piping arrangements and pump capacities in the Booster Pumping Station are flexible, in that the Air Base water can be boosted either from the ground-storage reservoir or from the Portsmouth supply. Water is metered and chlorine is fed proportionally to the varying rates of flow by means of two Venturi meters, one on the Air Base supply line and the other on the Portsmouth supply line. From this Booster Pumping Station there are two 12-inch pipelines extending to the grid system within the Base. The grid system consists of water mains varying in size from 12-inch down to 6-inch. These mains are laid in the various streets, such as Able St., Baker St., Charlie St., Dog St., Easy St., etc., and were designed to meet the fire-flow requirements on the Base. An auxiliary connection was made between the Base and the Portsmouth System by way of Rockingham Ave.

The new Haven Station gravel-packed well pumps water directly through the old supply main into the Portsmouth Distribution System. The so-called Portsmouth gravel-packed Well No. 3, which was not interfered with by the construction of the Base, but which is located within the Base area, is also used as a source of supply for the city of Portsmouth and is connected into the same pipeline extending from the Haven gravel-packed well. Portsmouth gravel-packed Well No. 3 is pumped by means of an electric-motor-driven deep-well pump.

This concludes a general description of the water system of the Air Base. The wells were constructed by the R. E. Chapman Co., the Off-Base pumping stations and pipelines by Verrier Construction Co., the storage reservoir by Graver Tank Co., and the On-Base system by Morrison-Knudsen-Landers and Griffin.

EXPERIENCES IN MANCHESTER, MASS., DURING FOREST FIRES

BY ALFRED S. DOANE*

[*Read June 13, 1957.*]

Manchester, Mass., is a residential town on the seacoast between Beverly and Gloucester. It has a year-round population of 3,400 and an estimated summer population of 4,500. It is bounded by the cities of Beverly and Gloucester and the towns of Hamilton, Wenham and Essex. Its area is a little less than eight square miles, about 60% of which is thickly wooded.

The water supply of the town of Manchester comes from two different sources, the Home Station and Gravel Pond. The Home Station supply consists of 20 driven wells and a large dug well, into which the driven wells discharge and from which the water is pumped into the distribution system. The available daily supply at this station is about 400,000 gal. The pumping facilities here are two Gould Triplex pumps—vintage 1909 which are belt-driven by two 50-hp. motors and are manually operated. This is the original supply and is currently being studied for additional supply.

The Gravel Pond supply, which is the main supply, is situated in Hamilton, about three miles away. This supply was acquired in 1908, the pond having an area of 45.4 acres. Adjacent to Gravel Pond and within the watershed area is Round Pond, a secondary supply, with an area of 36.8 acres. This pond is connected with Gravel Pond. The total watershed area owned by the town of Manchester, including both ponds, is approximately 250 acres. The pumping facilities at Gravel Pond Station consist of two 6-in. centrifugal pumps, having a capacity of 2.5 mgd, belt-driven by two 75-hp motors. These pumps are fully automatic, being controlled by telemeter with a transmitter at the base of the standpipe.

The only treatment at both stations is the addition of chlorine and Calgon.

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Our storage facility is a concrete standpipe, 72 ft in height, with a capacity of 1,025,000 gal. This is situated about a mile from the Home Station and two miles from Gravel Pond, was constructed in 1908 to replace a smaller steel tank that was located in a much lower section of Manchester.

Our distribution system was started in 1891 and to date consists of a little less than 29 miles. About six miles of the total is privately owned. There is a total of 240 hydrants, public and private, with an average pressure of 95 lb, a high of 115 lb and a low of 52 lb.

Before proceeding with the experiences of the Water Department during the recent forest fire, the following statistics are presented to show the magnitude of the operations between May 4th and May 10th. It is estimated that the fire covered an area of about 1,000 acres, and the following is a list of the equipment used with an estimated figure of 4,000 in manpower:

48 fire-engine companies
15 forest-fire trucks
6 Army Air Force fire pumpers
10 bulldozers
20 portable pumps
18 miles of hose
102nd Field Artillery Batt., fully equipped—trucks, communications and plane
American Red Cross—canteen, which fed all fire fighters, plus mobile canteen units and medical units
Salvation Army—mobile canteen units
Mass. Dept. of Public Works—trucks, equipment and communications
Civilian Defense—trucks, communications and equipment
Registry of Motor Vehicles
Dept. of Natural Resources—trucks, equipment and communications
Mass. State Police—36 police, complete with vehicles and communications
Manchester Police under Police Chief L. Allan Andrews plus several auxiliary units from neighboring communities
Manchester Fire Department under Fire Chief R. Ashton Hammond, who was in full charge of operations.

The Water Department's actual experiences during the forest fire in Manchester started on Saturday, May 4, 1957, when an assembly call was blown for more help in the Highwood area. Since it was Saturday, the majority of the crew had responded

individually, being call firemen. The Water Department had recently purchased a portable 4-in. centrifugal pump, and after a few fittings were located, it was moved into the fire area. At this time a few hydrants were being used, but there were several water holes that could be used to advantage. The pump was set up at one of these water holes at 4:00 p.m. on Saturday and was in operation until Sunday, May 5th at 8:00 p.m., when the water hole had become dry and the fire was believed to be under control.

On Monday, May 6th, the Fire Chief requested the use of three of the Department crew for clean-up work on hot spots. The rest of the small crew carried on with the preliminary work of a scheduled water-main cleaning operation.

Tuesday, May 7th, was the day scheduled to clean a 4,500-ft section of 12-in. water main. This necessitated closing all gates controlling the supply to the section of town called West Manchester and laying hose from one hydrant to another to by-pass these gates. The Fire Chief was contacted at 8:00 a.m., and it was his opinion that the cleaning operation could proceed as planned. The pressure cleaning tool had been inserted at the starting point, so the nipple was removed at the discharge point and the discharge pipe inserted. At 11:00 a.m. the operation had started and the tool had traveled a short way when the assembly call was sounded on the fire alarm. The reason for the alarm not being realized, work proceeded and at 12:40 had reached a point about 2,000 ft from the starting point, when it was requested that more water be supplied to the West Manchester area. The crew was immediately dispatched to open two 6-in. gates, and operations on the water-main cleaning project were temporarily secured, after which the crew returned to the shop. Upon arriving at the shop, the Department was informed that there was no pressure in the hilly sections of West Manchester and that the fire was racing towards several dwellings. The crew was dispatched to the discharge end of operations, the discharge pipe removed and the nipple inserted. All gates were opened, and at 2:10 p.m. all mains were full and West Manchester had its full capacity. In the meantime, both pumping stations were checked, and pressure was being maintained with 60 ft in the standpipe, although there was considerable use in the hilly sections. At 3:30

p.m. the Department was contacted by radio and requested to open the connecting gate with the Beverly Water System. This was done, after which Beverly was called, to inform them of the same and to request the Beverly pressure at the connecting point. There being a difference of about 20 lb, Manchester's being higher, the Fire Chief was contacted and, as a result, the gate was closed. At 5:00 p.m., the second pump was started at Gravel Pond, to maintain the 60-ft level in the standpipe, because the Home Station would of necessity shut down at 10:00 p.m.

Wednesday at 1:00 a.m. a routine check was made at Gravel Pond and, upon opening the door, the writer was greeted with a cloud of smoke, caused by a burnt-out coil, which had stopped both pumps. The electrician was called from Beverly, a new coil was installed, and the station was back in operation at 2:45 a.m. This was the only time that the standpipe fell below the 60-ft level, and then only 5 ft. At 7:00 a.m. the Home Station resumed pumping, and one pump was shut down at Gravel Pond. At 3:00 p.m. a change of wind had driven the fire to within a few hundred yards of a section of our power line that was overhead. This caused great concern, as there were several transformers off this line on poles, which, if damaged, would short out the power line. The Electric Company was called in to stand by, but fortunately the fire was controlled at this point.

Thursday, May 9th, at 1:00 a.m. the Department was called for lack of pressure in the hilly section of West Manchester. On responding to this call, it was discovered that water was being used from a tank truck and that no hydrants had been used in this particular area since the previous afternoon at 5:00 p.m. The hydrant was tested and found to have sufficient pressure to blow 30 ft across the road—although it must be stated that the man that tested the hydrant first tried to open it the wrong way. At 5:30 a.m. one of the hydrants along the route of the water-main cleaning, which had become plugged, freed itself, and there was plenty of water where it was not needed. At 7:00 a.m. the crew reported and was dispatched to inspect all hydrants that had been used or were being used, recaulking spuds and making minor repairs that were necessary.

Friday, May 10th, with the exception of one man, the crew

was released for forest-fire work. The rain, arriving at 7:00 p.m., put an end to a week of anxiety for all those concerned.

The following statistics are presented in regard to the amount of water used and the number of hydrants used:

Number of hydrants used	36
Number of hydrants used at one time, or connected and ready to be used	28
Total amount of water pumped, May 4 through May 10	7,952,000 gal
Estimated normal use	3,094,000 gal
Estimated fire use	4,858,000 gal

The above figures represent a new daily record of 1.65 mil gal and a new weekly record of 7.952 gal.

ALGAE AND OTHER INTERFERENCE ORGANISMS IN NEW ENGLAND WATER SUPPLIES

BY C. MERVIN PALMER*

[*Read September 16, 1957.*]

Water supplies of the six New England states may conveniently be considered together. Historically, topographically, and in other ways the factors influencing the use and condition of the water resources tend to be much the same for the whole region.

More than 50 per cent of the public water supplies of New England is derived from surface sources (1, 2). The surface water supply of the Boston Metropolitan District alone serves more than one-half the population of Massachusetts (3). Surface water is also used extensively in agriculture, industry, navigation, recreation, hydroelectric power generation, and transportation of wastes. It is by far the region's most valuable natural asset. Industrial development in New England was due to the quantity, quality, and availability of water (4).

The factors responsible for this favorable water supply situation in New England include abundant rainfall, which averages approximately 30 to 50 inches annually, uneven topography, ranging from high mountains to coastal plains, and geological formations which are composed primarily of hard, igneous, and metamorphic rocks rather than sandstone, shale, or limestone. These and other factors are responsible for the numerous rivers and streams and the many lakes and ponds throughout the whole region. The rivers and streams have been grouped into as many as 22 distinct drainage basins (4) while two states alone, Maine and New Hampshire, have a combined total of almost 4,000 lakes and ponds.

All surface water supplies of New England inevitably contain various types of living aquatic organisms, among which are algae, bacteria, fungi, and various minute aquatic animals. While

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many of these organisms might need to be considered in preparing water for use by a community, algae are the ones which produce most of the interference and nuisance problems during water treatment. Constant vigilance is required if they are to be kept under control. This account is limited to algae, together with certain other related organisms which are significant in water supplies in New England.

Algal growth is present in both the flowing and impounded waters but the amounts and types of growth tend to be quite different. Planktonic algae may often be abundant in lakes, ponds, and reservoirs, while they are present in much smaller amounts in flowing streams and rivers. The shallow portions of all bodies of water tend to have dense growths of attached algae. Algal productivity of New England water supplies will vary, in general, according to the topography and the underlying geological formations. Considering these two factors, the general regions for New England would include (a) the eastern coastal lowlands of Rhode Island, Massachusetts, New Hampshire, and Maine; (b) the eastern plateau of Connecticut, Massachusetts, New Hampshire, and Maine; (c) the broad central lowland of the Connecticut River basin; (d) the western highlands in Connecticut, Massachusetts, and Vermont; (e) the Taconic limestone region at the extreme western edge of these three states; and (f) the St. John River basin of northern Maine (5).

The least productive regions for algae are the western highlands and the eastern plateau where the lakes, ponds, and streams are underlaid by hard, insoluble metamorphic rocks. The Taconic region lakes, although influenced by the more soluble limestone, appear to be low in the phosphates and nitrates required for abundant algal growth. The central lowland is underlaid by soluble sedimentary and igneous rocks rich in iron and the lakes tend to be supplied with a sufficient quantity of phosphates and nitrates to support an abundant growth of algae. The eastern coastal lowlands are generally well drained but contain a considerable number of small lakes. Bodies of water in the St. John River basin region of northern Maine undoubtedly vary in productivity, depending upon the amounts of nutrients they receive by drainage from the surrounding soil. The potato farm lands in

this region are heavily fertilized and could be the source of nutrients for nearby lakes and streams.

The surface waters of New England which are utilized for public water supplies are contained mostly in lakes and in reservoirs where the water has been impounded from limited drainage areas. A few cities and towns use river water. Problems caused by algae and other interference organisms would tend to be less in the supplies from rivers, especially those with fast currents. Other problems would be encountered, however, due to the heavy pollution load of river water. The extent of the problems caused by algae in lakes and reservoirs depends, in addition to the factors referred to above, upon such conditions as the amount of marginal shallow water, the extent of swampy land in the drainage area, and the depth of the water.

While there are many gaps in our knowledge of the fresh-water algae of New England, it is more complete than for most of the other sections of the country (6, 7). Most of these algae may be placed for convenience into four major groups: the blue-green algae, the green algae including the desmids, the diatoms, and the flagellate (swimming) algae (8). New England was a favorite collecting area for America's earliest algologists (9) and even before 1890 papers had been published on the algae of Maine (10) and the desmids of Massachusetts (11), and a list had been prepared of some algae of Rhode Island (12). Many later papers were written including ones on blue-green algae of New England (13), algae of Connecticut (14), desmids of New Hampshire (15), plankton of lakes in New Hampshire (16) and Connecticut (17), fresh-water algae of New England (6), the yellow-green algae of New England (18), the algae of Vermont (19), and the phytoplankton of a reservoir in Massachusetts (20). Probably the most prolific writer on New England algae was F. S. Collins (21) who in 1909 published a comprehensive work on the green algae of North America (22).

The study of algae in relation to water supplies also had an early start in New England. Before 1890, algological examination of water supplies had been initiated in Massachusetts and Connecticut (23) and the work of the men who opened this field laid an excellent foundation for present day practices in algal detection and control. Boston was the first city in the United

States to establish a municipal laboratory for biological analysis of the water supply (23).

New England has an algal flora which is rich in its variety of forms and occasionally in its abundance. The region is particularly well known for its many kinds of desmids which appear to be more closely related to those in Newfoundland and northern Europe than to those in other areas in North America (9). The flagellate and blue-green algae are well known for their production of odors and tastes while the diatoms are important both because of odor production and clogging of sand filters.

The relative abundance of groups of algae in various types of water habitats is indicated in figures for Massachusetts (Table 1) which are based upon early work by the State Board of Health (23). The general picture is probably much the same today as when these figures were compiled. The decided difference in quantity between the plankton in rivers and that in reservoirs, ponds, and lakes is evident, as is the fact that ground waters contain few algae unless they are stored in basins or infiltration galleries exposed to sunlight.

TABLE 1.—ALGAE IN MASSACHUSETTS WATERS
(Data given are averages of 10 samples from each type of habitat.)

	Areal Standard Units per ml.				
Habitat	Green Algae	Blue-green Algae	Diatoms	Flagellate Algae (+ Protozoa)	Total Algae
Well waters	0	0	1	0	1
Infiltration galleries	1	1	13	6	21
Rivers	11	6	32	11	60
Spring waters	18	0	49	0	67
Reservoirs	83	86	713	83	965
Ponds and lakes	99	70	702	117	988

As to seasonal distribution of phytoplankton in New England, the four groups of algae are, in general, quite different from one another. The most abundant growth of green algae is likely to occur in June, July, and August, while for the blue-green algae it is in August, September, and October. The diatoms tend to have two periods of peak growth, one in November, December, and January, and the other in April and May. The

flagellate algae, as a group, may reach their best growth in March, April, and May. There are, of course, many exceptions to these general statements, especially when particular bodies of water or individual genera or species of algae are considered.

In a region such as New England where most of the surface water supplies are taken from lakes and reservoirs the problems caused by algae tend to be of several types and relatively frequent in occurrence. They include odor, taste, color, filter clogging, interference with coagulation and chlorination, and changes in pH, dissolved oxygen, organic content, or other physico-chemical constituents of the water.

Odor, sometimes accompanied by taste, is most frequently mentioned in the many published articles on algae in public water supplies. Many cities and towns in Massachusetts have referred to this problem, and a few papers indicate that odor and taste are encountered in water supplies in Connecticut (24, 25, 26, 27), Maine (2, 28), Rhode Island (29, 30), and New Hampshire (31). More than two dozen genera of algae have been reported as causing odors. The odor-producing algae listed for at least two of the six states are the diatoms *Asterionella, Melosira, Synedra,* and *Tabellaria*; the blue-green algae *Anabaena, Anacystis* (*Microcystis*), *Aphanizomenon, Cylindrospermum,* and *Gomphosphaeria* (*Coelosphaerium*); the flagellate algae *Ceratium, Dinobryon, Eudorina, Mallomonas, Pandorina, Peridinium, Synura, Uroglenopsis,* and *Volvox*; and the desmid *Staurastrum.* The five most frequent producers of prominent odors would appear to be *Anabaena* with its septic odor; *Asterionella* with its geranium to fishy odor; *Dinobryon* with its fishy odor; *Synura* with its ripe cucumber to fishy odor and bitter taste, and *Uroglenopsis* with its cucumber to fishy odor. The most common type of odor reported, however, is the musty, vegetable, swampy or grassy odor (27, 32, 33) and it is possible that the causal organisms such as *Dictyosphaerium* are frequently overlooked (34). The musty or vegetable odor is considered to be relatively difficult to remove (33). The fishy odor is referred to more frequently in the earlier records (35, 36) than in recent reports.

Phenolic to medicinal odors have been encountered a number of times. These are not likely to be due directly to algae or other microorganisms. In Connecticut it is reported that the

phenolic "taste" occurs usually after a rain, with run-off reaching the reservoir from freshly surfaced pavements containing a coal-tar base (32).

In 1909, Tighe, reporting on odors and tastes in the water supply of Holyoke, Massachusetts (36), made an interesting comment about *Uroglenopsis*. He stated that no odors or tastes produced by organisms were more easily detected or harder to forget than those produced by "*Uroglena*" (*Uroglenopsis*), and that the odor was so pronounced it was readily perceptible even in the counting cell.

Algae appear to be the most important cause of shortened filter runs in the majority of New England treatment plants. This applies to both slow and rapid sand filters. Diatoms are one of the frequently responsible groups because of their rigid silica walls which remain undecomposed after death of the cells, permitting dead as well as living diatoms to clog the pores of the filter.

In a slow sand filter the beneficial surface slime layer (Schmutzdecke) does not require the presence of diatoms to function and it is claimed that their presence probably does more harm than good by speeding the clogging of the filter (23). In one plant the diatoms were reported to have completely cemented the upper six inches of sand so that no water could pass through (35). A slow sand filter in Massachusetts which became clogged in 25 days was found to have a very large number of algae on the surface, including more than 2,500,000 *Tabellaria* and 1,000,000 *Synedra* over each sq. cm. (23). Most of these had grown on the filter as a result of reproduction by the few which had been screened from the water.

In rapid sand filters, runs of 75 to over 100 hours have been reported as frequent (26), but clogging by algae has often reduced the filter runs to less than 10 hours if adequate control measures were not used (37). One treatment plant in Connecticut reported that the shortest monthly average filter runs each year were in August, September, and October while the longest monthly average filter runs occurred in March and April (38).

The blue-green algae are generally considered to be abundant during the late summer and early fall when the short filter runs occurred. However, while summer growths of algae are stated to

be the most troublesome (23), the only algae which are reported by their genus names as filter cloggers are generally diatoms, especially *Asterionella, Melosira, Nitzschia, Synedra,* and *Tabellaria* (33, 37, 39). In fact, some New England records indicate that diatoms often are abundant throughout much of the year. In Moosehead Lake, Maine, diatoms were the most abundant of the plankton organisms in practically every sample (40). In Quabbin Reservoir, Massachusetts, records of phytoplankton, from May to October, indicate that the diatoms dominated in all but four of the weekly collections and averaged 79.5 per cent of the total net phytoplankton (20).

One Connecticut plant expected filter troubles whenever the diatoms reached 1000 organisms per ml. (37), while a plant in Massachusetts reported 673 areal standard units per ml. of *Melosira* as sufficient to cause filter clogging (33). At one treatment plant in New Hampshire it was assumed that decreased filter runs could be expected during the summer whenever the water temperature reached 65° F., causing increased algal growth (31).

Algal growths are found to interfere also with coagulation, with chlorination, and with the physico-chemical characteristics of the finished water, requiring the plant operator to modify the treatment according to the effects of the algae on floc formation, turbidity, pH, and on the amount of residual chlorine. These problems are in addition to those concerned with direct control of algae, and with odors, tastes, and color.

A report from Danbury, Connecticut, (37) gives a vivid description of the effect of algae on coagulation and chlorination: "The felting and dyeing processes of our major industries demand a water free of color, turbidity, iron, and aluminum, and with low pH and hardness, both held to a constant value. A weak floc, induced by large-scale algae concentrations, will pass appreciable amounts of these interfering substances through the filters. Daily blooming of algae in our shallow reservoirs causes the raw water pH to vary from 7.0 to 10.0 in a few hours." As algae increase in the raw water ". . . small daily adjustments in chemical feed, equipment, and operational methods keep pace with them in order to maintain our predetermined optimum conditions such as: maximum turbidity of 2.0 on the filters, maxi-

mum pH of 6.7 in the treated water, minimum filter runs of 23 hours, minimum rates of flow of 70,000 gallons per foot head loss per filter, minimum floc size in the last flocculator of 2.0 mm. . . . Normally we obtain a large fragile floc particle quickly, without agitation. However, we use the flocculators (agitators) with certain growths, particularly *Coelosphaerium, Anabaena,* and other free floaters, for we find that, while we get a smaller, poorer floc, we get settled water of better quality, that is, lower turbidity and color applied to the filters, which is, after all, what is wanted." In reference to the ability of algal blooms to cause a sudden rise in pH of the raw water, the report states that: "In the early days of operation, nothing was known of the activity of these forces and the operators were continually puzzled by the sudden inexplicable shift to a settled water of poor quality. During the high peak of the pH cycle there was insufficient alum to lower the pH to the point of floc formation."

Color in water has been a persistent problem in many New England water supplies. This is most frequently due either to humus in shallow areas from which a brown color derives or to plankton algae when the water becomes some shade of green, brown, or red, depending upon the particular kind of alga present. Color from certain very minute flagellate algae such as *Chlamydomonas* (36, 41) and *Gonyostomum* (23) is sometimes difficult to control, especially for water works having no facilities for coagulation or filtration or when the odors develop in open reservoirs of a distribution system. A prodigious growth of the filamentous alga, *Oscillatoria prolifera,* has produced a pink to copper-red color in Massachusetts, while in New Hampshire the alga, *Aphanizomenon,* frozen into the lake ice, gave it a distinct green color (23).

In general, any microscopic algae, in producing visible blooms, would thereby produce coloration in the water. Blooms and other bothersome algal growths in the lakes and reservoirs have been reported from many localities and in all six states (23, 29, 42, 43, 44, 45). Three to five times more green pigment (chlorophyll) from plankton algae was found in the lakes of the central lowland region than in those of the eastern plateau, the western highlands, or the limestone region (46). In Massachusetts the diatoms were present in more lakes and reservoirs in

numbers often above 1000 per ml. than were the other algal groups (Table 2) (23).

Attached algae and water weeds can become a problem in the shallow margins of lakes and reservoirs. Without the use of sodium arsenite these forms are often difficult to control (47). The common procedure is to cut them or pull them out by the roots. One Connecticut utility riprapped the shore of the reservoir in an attempt to eliminate their growth (32). *Chara, Nitella, Ulothrix, Cladophora,* and *Calothrix* are some of the attached algae which have been encountered (14, 36, 48). They also may contribute to the organic content of the water, produce odors in the water or in the air along the shore, clog inlet screens, and serve as nesting areas for the development of many kinds of organisms (26, 32, 43, 49, 50). In the lakes of northern Massachusetts, the commonest filamentous form is the green alga *Oedogonium* (51).

TABLE 2.—OCCURRENCE OF ALGAL GROUPS IN MASSACHUSETTS LAKES AND RESERVOIRS

	No. of lakes and reservoirs			
Algal group	Often above 1000 org. per ml.	Occasionally above 1000 per ml.	Usually between 100 and 500 per ml.	Below 100 per ml.
Blue-green algae	7	10	18	22
Green algae	5	11	29	12
Diatoms	24	8	19	6
Flagellate algae and Protozoa	8	7	35	7

A number of methods have been employed in New England to determine the presence of interference algae in the water. One of the simplest tests was that used by a practical superintendent of a treatment plant. It consisted of taking a sample of water in a clean bottle, holding it up to a good even light and observing for algae in the form of coarse turbidity (52). Records of raw water showing high pH, high threshold odor, a distinctive odor, high color, and increased turbidity as well as reduced length of filter runs may all be indicative of an increase in the number or a change in the kinds of algae present.

Microscopic analysis for plankton organisms is carried out by a number of water laboratories and the interpretation of such records is the basis for precise methods for control of algae and other interference organisms (20, 23, 28, 29, 37, 53, 54, 55). In New England, the areal standard unit is commonly employed for enumerating algae in water supply reservoirs and lakes (34). In one plant the microscopic records are plotted on semi-logarithmic paper in order to make apparent any changes in the rate of reproduction of any particular organism (37). Satisfactory interpretation of plankton records also requires comparison of current records with earlier records for the same body of water.

Control of algae in New England is a much publicized subject. The only common algicide used has been copper sulfate which appears to be effective if a sufficient dosage is applied before the algae become abundant (37, 39, 53). Swartz, Monie, and others have emphasized that there is no fixed dosage of copper sulfate suitable for any one reservoir or any one organism, as several factors, including temperature and pH, must be considered before the proper dosage is determined (55, 56). Woodhull does not advocate the practice of indiscriminately treating a reservoir with copper sulfate, with no accompanying data to indicate the need and proper dosage (32).

Algicides used in limited concentrations tend to be selective in their toxicity. Destruction of one kind of alga sometimes paves the way for rapid growth of another kind more resistant to the algicide (57). Houser has described such a case at Rockport, Massachusetts, in which the elimination of *Tabellaria* by copper sulfate was followed by a bloom of *Chlamydomonas* (58). Indiscriminate use of an algicide may upset the balance of existing aquatic life and make possible unrestricted growth and dominance of a single kind of alga, causing more serious problems than the possibly inoffensive balanced, mixed growth (32). Riley reports the presence of small amounts of copper naturally present in some Connecticut lakes which may be high enough during the autumn to be toxic to some animals and plants (59).

Copper sulfate has been used for control of algae in raw water supplies in at least five of the six New England states, including such communities as Augusta, Maine; Durham, New Hampshire; Rockland, Massachusetts; St. Albans, Vermont; and

Torrington, Connecticut (28, 31, 60, 61). Its use for the control of algae under ice has been reported as successful (62).

In addition to its bactericidal effect, chlorination has been used in New England for control of taste and odor and algal growths, for longer filter runs, better floc formation, and for maintenance of pipe-line capacities (25). All of these cases involve interference micro-organisms, living or dead, or organic debris resulting from their partial disintegration. Prechlorination for better floc formation and longer filter runs does not necessarily improve the taste, odor, or appearance of the water (24). Chlorination for control of odors has included break-point chlorination and, to a lesser extent, the ammonia-chlorine process. Marginal chlorination has been much less effective in odor control (32). Tests with chlorine-dioxide in Massachusetts indicate that it does reduce various kinds of tastes and odors (3).

Activated carbon for odor control is reported to be effective when used prior to rapid sand filtration (26, 32). However, plants in New Hampshire and Connecticut report filter runs decreased 25 to 50 per cent when carbon is used in this manner (31, 37). Two plants in Massachusetts report activated carbon used in the reservoir to be very effective and rapid in eliminating tastes and odors (61, 63), while a Connecticut plant found that even large doses in the reservoir were disappointing (37).

Still other methods aimed at reducing the problems caused by algae have been reported in various parts of New England. Selection of supplies free from sewage pollution is the common procedure in the region (1, 3, 4, 48, 50). The selection of reservoir sites which would eliminate shallow margins and swampy places in the drainage area and the clearing or stripping of the land before filling constitute attempts to discourage algal growths (23, 27, 32, 43). Construction of several intakes at different depths in the reservoir, and of more than one reservoir to permit alternate use have circumvented large plankton growths (27, 29, 32, 33, 39, 49). The covering of storage reservoirs to eliminate algae was urged by Forbes in Massachusetts as early as 1888 (64). Limnological studies in Connecticut indicate that knowledge of the phosphorus, nitrates, and other nutrients in the water may be used to predict the kinds, abundance, and periodicity of plankton organisms in lakes and reservoirs (65, 66, 67).

The use of a microstrainer for removal of algae from the water supply has been tested at Danvers, Massachusetts (68).

Comparatively little information has been published on interference organisms other than algae in New England. Slime deposits have been encountered on reservoir walls and in water mains. No iron bacteria were found but break-point chlorination in the main and copper sulfate in the reservoir caused reduction in the amount of slime present (39, 69, 70). Clear wells and ground water wells have also been troubled with slime growths and in the latter *Crenothrix* and sulfur bacteria were present, producing an offensive odor. Treatment included chlorination followed by flushing of the wells (30, 49). Corrosion and tuberculation have been reported in water mains of Massachusetts, Rhode Island, and Connecticut, and the claim was made that various bacteria were, in part, responsible (71, 72).

With a considerable number of treatment plants using surface waters and having no facilities for coagulation and filtration (60), it is to be assumed that various organisms would be found at least occasionally in the treated water. Reports of these, however, are not common. Chlorination undoubtedly reduces to a minimum the amount of bryozoa and other attached growths in the mains. Nematodes and other organisms may be common in distribution systems and in the lower levels of sand filters, even when prechlorination is practiced (24).

Biological problems in the near future will include those associated with the further improvement in quality and palatability of public water supplies. Consumers will request a product freer of tastes, odors, color, and turbidity (2), and industrial users will demand a water which does not vary in physico-chemical characteristics from established standards (37). Additional supplies will need to be tapped and these undoubtedly will include some with high algal productivity. Connecticut is already concerned with a sharp increase in the overall use of water, especially for irrigation, with cities competing for supplies, and with ground water being removed at an alarming rate through gravel-packed wells (73). The rapid expansion of recreation facilities and the increasing interest in wildlife preservation will also increase competition for protected watersheds free from gross pollution. Demands for multiple-use reservoirs and lakes will increase. Future

care and treatment of public water supplies will undoubtedly include standardized biological examinations of all raw and possibly of treated water, with frequent adjustments in the treatment based upon the biological data obtained. New England is in a favorable position to be a leader in this movement.

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THE NEW WATER TREATMENT PLANT FOR BILLERICA, MASSACHUSETTS

BY THOMAS R. CAMP*

[*Read September 17, 1957.*]

The town of Billerica, located along the Concord River just south of the city of Lowell, constructed its water supply in 1898 to serve about 1800 persons. The original supply consisted of 2-½-in. driven wells in Hutchins Meadow in the valley of the Concord River in North Billerica. The water drawn from these wells initially was almost free of iron and manganese, but the iron and manganese content gradually increased. By 1920 the original tubular wells were so badly clogged with iron rust that they had to be supplemented by a new field of 4-in. wells, located to the east of the original field and nearer the river. The iron and manganese content of the water from the new wells also increased until by 1930 the iron content exceeded 4 ppm.

In 1931 an extensive exploration was made for a new groundwater supply, including 62 soundings and borings in the Shawsheen River Valley and 54 in the Concord River Valley. Test wells in the Shawsheen Valley indicated water with an average iron content of about 0.7 ppm. The Concord River Valley test wells indicated a more abundant yield and water of somewhat better quality. As a result of these tests, two gravel-packed wells were constructed within 50 ft of the Concord River, just south of the existing 4-in. wells.

When first placed in operation, the new gravel-packed wells produced water of acceptable quality, but the iron and manganese content increased and the wells gradually clogged.

In 1947, the works were supplying about 6,200 people out of a total population of about 8,000 in the town of Billerica. The capacity of the wells was becoming critical, and the water quality was growing poorer. A comprehensive engineering investigation was made by our firm of six alternate methods for securing an adequate permanent water supply of good quality

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for the town, including the following: (1) Metropolitan District water from Wachusett Reservoir, (2) Metropolitan District water from Boston, (3) purchase of water from Lowell, (4) development of a new source of ground water low in iron and manganese, (5) the use of the Concord River water after filtration, and (6) an additional well and an iron-removal plant at the present works.

In a report to the town dated April 5, 1948, we recommended the immediate construction of the third gravel-packed well and the construction of an iron- and manganese-removal plant for the treatment of the well water, this plant ultimately to be expanded to treat Concord River water. We further recommended pilot-plant studies on the treatment of the well water prior to commitments on the construction of the treatment plant.

A small pilot plant was operated for about four months during the latter part of 1948. In our report of January 5, 1949, to the town, we described the studies in connection with the operation of the pilot plant. These studies indicated that both iron and manganese could best be removed from the well water by a treatment process consisting of breakpoint chlorination with a dose of 5 to 8 ppm of ferric chloride, followed in turn by filtration through rapid sand filters. The treated water would have a pH of about 10.2 and a hardness slightly less than the hardness of the raw water, which varied from 25 to 50 ppm. Inasmuch as enabling legislation had been introduced to permit the Metropolitan District Commission to supply water to Lowell and the surrounding towns, we recommended that no action be taken on the construction of the proposed treatment plant, pending the outcome of the proposal to supply water to Lowell from the Metropolitan system.

In the meantime, the third gravel-packed well along the Concord River was constructed and placed in operation. The 1950 U. S. Census revealed about a 30% increase in population for the town of Billerica in five years. The pressure for more water increased. Since nothing was done about furnishing Metropolitan water to Lowell, the town was compelled to take action in 1954. The plant described in this paper was constructed as a result of this action. It was found necessary to increase the

capacity of the plant greatly over that originally proposed, and to take water from both the Concord River and the wells.

The iron content of the well water had increased from an average of about 0.3 ppm in 1932 to an average of about 1.4 ppm in 1948. The manganese content had increased from about 0.29 ppm on the average to about 0.45 ppm on the average in the same period. Analyses of the Concord River indicated a variable iron content, averaging about 0.45 ppm with no increase during the period from 1932 to 1948. The concentration of iron in the river water fluctuated widely, with a maximum up to 2 ppm. Infrequent tests for manganese indicated an average content of about 0.1 ppm in the river water and a maximum of about 0.3 ppm. The hardness of the river water ranges from about 20 to 40 ppm; the color from 40 to 90 ppm; and the turbidity is generally less than 10 ppm. Both the well water and the Concord River water are corrosive, with a pH of about 6.5. The well water contains up to 40 ppm of carbon dioxide and the river water considerably less. The Concord River water is, in addition, polluted by municipal and industrial wastes at several communities upstream, usually has a swampy odor, and is subject to algae and duckweed growths. Our problem was to design a treatment plant which would function satisfactorily with either well or river water, or combinations thereof.

The Billerica water-distribution system, which had been built up over the years, consisted principally of 6-in. to 12-in. unlined cast-iron pipe, extending for about five miles in the north-and-south direction and for about five miles in the east-and-west direction throughout the town. Our 1948 studies of the distribution system showed that the pipelines were badly corroded on the interior with extensive deposits of rust. The system had lost capacity, the loss ranging from about 20% for pipes ten years old to more than 70% for pipes 50 years old. The fire flows available throughout the system were found to be woefully inadequate. To remedy this defect it was necessary to reclaim the capacity in the existing mains and construct reinforcing mains where necessary.

It is common knowledge that with corrosive New England waters the cleaning of cast-iron mains is ineffective to restore and maintain capacity, unless accompanied by cement lining in

place or alkali treatment of the water to high pH values. Our experience elsewhere in New England indicates that hydraulic capacity can be maintained fairly well with cleaning at intervals of eight to ten years if the pH of the water is maintained at about 10. This procedure is considerably cheaper than cleaning and cement lining in place and has the additional advantage of protecting the household plumbing systems. The plan was therefore recommended for Billerica, and the proposed new water treatment plant had to include facilities for treatment of the water to a pH of 10. In order to avoid the increase in hardness which would result if lime were used, sodium hydroxide was adopted as the alkali.

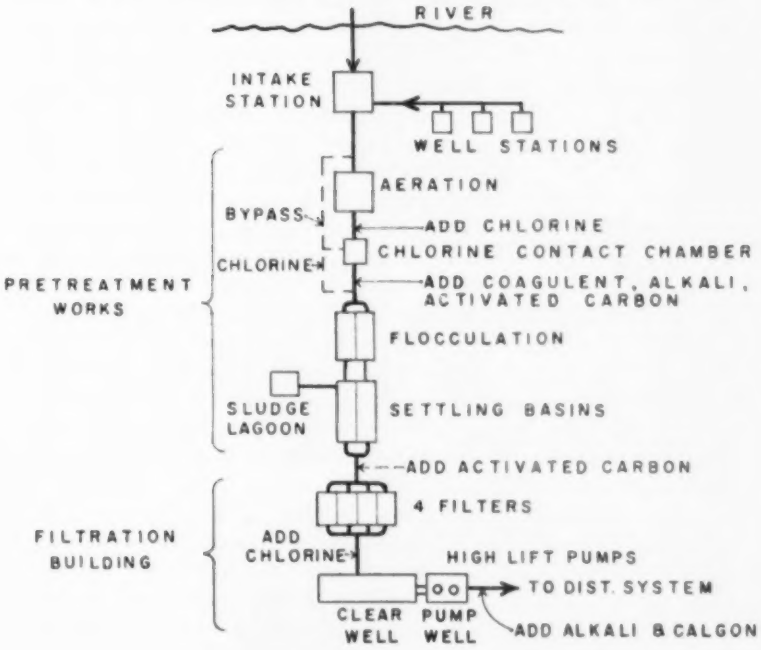
During the final design of the treatment plant, when it was apparent that facilities would have to be included for taking water from the Concord River, laboratory jar tests were made to determine the best method of treatment of the river water. These tests indicated that better removal of iron and color could be obtained by coagulation with alum at low pH values than with an iron salt at a pH of 10. It was found, however, that breakpoint chlorination was required with the river water as well as with the well water. Similar jar tests were then run on the well water with alum coagulation. These tests indicated that this method of removal of iron and manganese from the well water was not quite as effective as was coagulation at a pH of 10 using ferric chloride. It was apparent from these tests that the plant had to be designed to permit treatment by either method.

Studies indicated that it would be better and cheaper to purchase sodium hydroxide in a 50% water solution and feed it as a solution rather than to handle it in dry form. In order to provide flexibility for feeding either alum or one of the iron salts as a coagulant, it was decided to feed the coagulant as a solution also. It was subsequently found that alum solution could be purchased in tank-truck lots somewhat more cheaply than solid alum could be purchased. There are, therefore, no dry feeders in the treatment plant, except the one for feeding powdered activated carbon.

The treatment plant as constructed has a present capacity of 3.5 mgd with four filters operating at a rate of 3.4 gpm per sq ft of filter area. The flocculation and settling basins consist of two

units each in parallel. The remainder of the plant has a hydraulic capacity of 5.25 mgd such that a 50% increase can be made in the capacity of the plant by the construction of two additional filters and one additional flocculation and settling basin.

Figure 1 is a flow diagram of the treament plant. The intake



FLOW DIAGRAM – BILLERICA, MASS.

FIG. 1

station consists of two passes for taking water from the river through coarse racks and fine screens into a pump suction well. One of these passes is equipped with a traveling water screen with ¼-in. openings, and the other pass is presently equipped with a hand-cleaned screen for emergency only, with provisions

for the installation of a second mechanically cleaned screen when it is needed.

Two variable-speed, vertical turbine pumps are installed in the suction well of the intake station to deliver raw water to the pretreatment works. Water can also be delivered to the suction well from the gravel-packed wells for the complete use of well water or for mixing with river water. One raw-water pump at full speed can provide substantially the 3.5-mgd capacity of the existing plant with the aerator bypassed. When using the aerator, or in the future when the plant capacity is expanded, it will be necessary to operate both pumps simultaneously. The pumps are started and the speed is selected manually by the operator as required to fit the total rate of filtration. An automatic butterfly valve in the force main at the pretreatment works is actuated by the water level in the sedimentation basins, to equalize the rate of pumping with the rate of filtration. Automatic butterfly check valves in each pump discharge line open after the pumps start and close prior to pump shut-down. In the event of power failure, they close at a controlled rate to prevent water hammer while water passes briefly backward through the vertical pumps to the suction well. Figure 2 is a view of the intake station from the river side, with the aerator and pretreatment works in the background, to the left.

The filtration building was located at a relatively high elevation because of ground water and the possibility of flooding from the river. Therefore, the pretreatment works are also entirely above the ground, in order to permit gravity flow to the filters. The spray aerator is on the roof of the pretreatment works and consists of fifteen 2-½-in. "Sprayco" bronze nozzles, with internal centers reversed to reduce the angle of the cone of spray. These nozzles have a capacity of 2.5 mgd; so that if the plant is operating at the maximum rate of 3.5 mgd, it is necessary to by-pass a portion of the raw water around the aerator. Provision has been made to expand the capacity of the aerator when the plant capacity is increased in the future. The primary purpose of the aerator is to remove carbon dioxide and thus reduce the cost of sodium hydroxide required for its neutralization.

The aerator is located on top of the chlorine contact chamber, as shown in Figure 3, which also shows the two parallel

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FIG. 2.—INTAKE STATION AT BILLERICA, WITH AERATOR AND PRETREATMENT WORKS IN BACKGROUND.

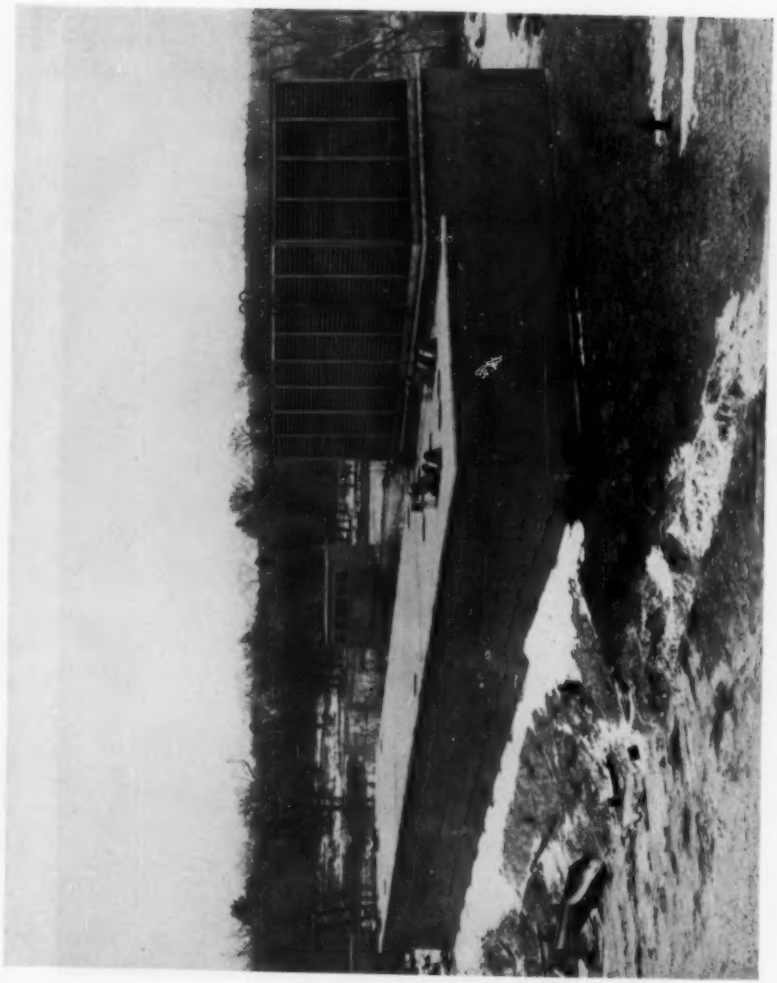
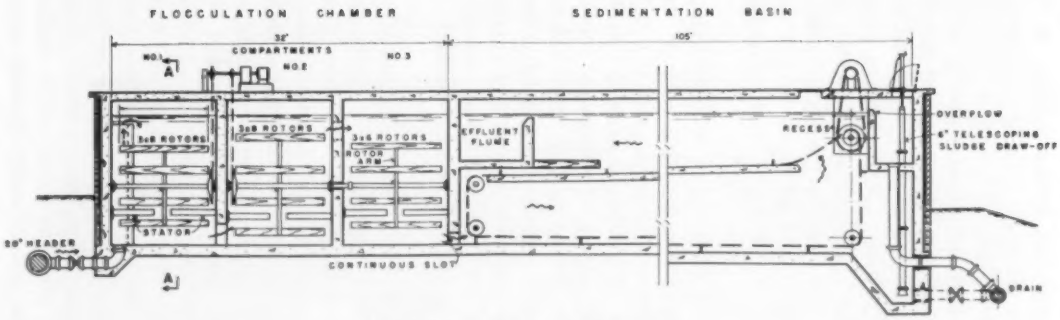


FIG. 3.—VIEW OF PRETREATMENT WORKS AT BILLERICA.

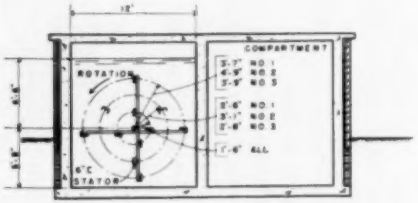
flocculator-sedimentation units and the intake station in the background. The chlorine contact chamber, with around-the-end baffles, provides a detention period of 18.5 min at 3.5 mgd capacity. This unit will be extended when the capacity of the plant is increased. Chlorine solution may be introduced into the effluent pipe from the aerator, just ahead of the chlorine contact chamber. The effluent from the chlorine contact chamber passes through a cast-iron pipeline under ground to the upstream end of the two parallel flocculation chambers in the foreground of Figure 3. The coagulating chemicals and activated carbon may be added in the pipeline between the chlorine contact chamber and the flocculation chambers.

The above-described sequence of adding the chemicals is essential, if coagulation is undertaken at high pH with an iron salt, in order to provide an adequate chlorine contact period at low pH for effective bacterial kill. With alum coagulation at low pH, however, the detention period in the flocculation and settling basins is also available for chlorine contact period. Provision has been made, therefore, to permit the dosing of activated carbon into the inlet pipe of the chlorine contact chamber and chlorine solution into the outlet pipe from the chlorine contact chamber. This method of operation is now in use and promises to save on both chlorine and activated carbon.

Figure 4 shows a longitudinal section through a flocculation chamber and the sedimentation basin into which it discharges, and also a cross section through a flocculation chamber. Each flocculation chamber consists of three compartments in series. Horizontal-shaft mechanical mixers provide tapered agitation by means of a high-speed shaft in the first flocculation compartment and a lower-speed shaft in the next two compartments. The size of the rotor blades is smaller in the final compartment, and they are closer to the drive shaft. In all compartments, the rotor arms are attached at mid-shaft with a total of eight rotor blades. Each end wall has three half-length stators positioned midway between the rotating blades and 120° apart. The treated water enters the first flocculation compartment near one corner at the surface and leaves that compartment at the diametrically opposite corner near the bottom. The same pattern is repeated in the second compartment, and the effluent discharges from the third compart-



LONGITUDINAL SECTION



SECTION A-A

PRETREATMENT WORKS

BILLERICA, MASS.

FIG. 4

ment into the sedimentation basin through a continuous slot across the bottom.

Each sedimentation basin has two floors upon which floc may settle. The effluent from the flocculation chamber passes over the bottom floor to the far end of the basin, thence upward and in the reverse direction over the tray to the effluent flume adjacent to the flocculation chamber. The same sludge-collector mechanism cleans both floors. The flights move along the bottom floor to the sludge hopper at the far end of the basin and thence upward and across the tray to the influent end of the basin. Sludge settled on the tray is dropped to the bottom floor at the influent end of the basin. To prevent short-circuiting, a narrow pass has been built above the tray adjacent to the flocculation chamber, which has sufficient length so that one of the wooden flights is always within the pass. Sludge is withdrawn by gravity through a telescoping sludge draw-off, as shown on Figure 4.

For architectural reasons the pretreatment works were not constructed contiguous to the filter building. The sedimentation-basin effluent discharges from the effluent flume through a cast-iron pipeline under the ground to the filter building. A front view of the filter building is shown in Figure 5. The filter building surmounts a filtered-water reservoir of 0.5-mg capacity. The one-story building with the glass front to the right of the figure is the chemical-feed room. The two-story building to the left is the filter building, with the filters occupying the lower floor and the operating gallery the upper floor. The first floor of the filter building proper is occupied by the pipe gallery and the wash-water and high-lift pumps. The second floor is occupied by the filter operating tables, a laboratory and the switchboard.

The four filters, each 18 ft by 10 ft, are equipped with porous alumina plates, supported on stainless steel bolts set in the concrete. Above these plates there is a 30-in. depth of sand, surmounted by an 18-in. layer of anthracite coal. The sand is screened between a No. 30 and a No. 16 U. S. sieve and ranges in size from about 0.59 mm to about 1.19 mm. The anthracite coal is screened between a No. 12 and a No. 16 U. S. sieve, and is sized from about 1.19 mm to about 1.68 mm. These sizes keep the coal on top of the sand during backwashing with practically no intermixing. The purpose of the coal is to encourage penetration of the floc into the bed, so as to produce long filter runs.

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FIG. 5.—FRONT VIEW OF FILTER BUILDING.

A system of acid-distribution pipes is installed below the porous plates of each filter to permit acid cleaning, and a mercury manometer is provided for each filter, to measure the losses through the plates while backwashing. New, clean porous plates have a loss of about 0.7 ft at a wash rate of 24-in. vertical rise per minute.

Filter operation is controlled by standard operating tables in conjunction with hydraulically operated, rubber-lined butterfly valves. Such valves have been used throughout the filter piping system. The loss-of-head and the rate controllers, including the summation equipment, are all operated by air.

Two vertical turbine pumps suspended in the pump well provide water for filter backwashing, and a gear-operated butterfly valve in the discharge pipe permits partial throttling of the washing rate, with further throttling by the backwash gate controlled from the operating table. Each wash-water pump has a capacity of about 6.1 mgd under the highest operating head to which the pumps will be subjected. This will permit backwashing at rates up to about 40-in. vertical rise per minute with a single pump. The sand beds must be expanded about 8% to place all of the sand in suspension. The wash rate available is sufficient to accomplish this objective at temperatures up to 85° F.

Two high-lift pumps for pumping into the distribution system have been installed, with space for a third unit. Each unit has a capacity of 2 mgd. They are of the vertical turbine type with six stages and are suspended in the pump well. Automatic cone valves are employed on the discharge side of each pump. These valves open after the pump has been brought up to speed and close prior to the shut-down of the pump. If power failure occurs, the cone valve will close within the adjustable period of 60 to 120 sec while water is passing from the distribution system back through the pump into the suction and clear wells.

All chemical and dosing facilities are contained within the chemical room, which is a part of the filter building. A separate room has been partitioned off for the chlorine equipment, accessible only from the outside. This room contains two chlorine machines of the solution-feed type, each having a capacity of 300 lb per day. The machines are controlled manually. In the

chemical room proper there are two Calgon feeders, two 2,000-gal alkali tanks together with two alkali feeders, and two 2,000-gal, rubber-lined coagulant tanks with coagulant feeders. All four 2,000-gal tanks have propeller-type agitators for mixing dilute solutions or for use in mixing and dissolving dry chemicals if they are employed. Figure 6 is an interior view of the chemical room. A two-story activated-carbon feeder is loaded from a carbon-storage room on the floor above. This feeder is shown in the background of Figure 6.

FIG. 6.—VIEW OF CHEMICAL ROOM.

Operation of the plant on a 24-hour basis will not be required in the early years, particularly if river water is used at the present plant capacity. The gravel-wall wells have a combined capacity of about 1 mgd and if, for any reason, it becomes necessary, the plant can operate unattended at night on only

well water. Whenever river water is used an attendant will be present. To permit unattended operation, a number of automatic features were provided to sound alarms, to prevent flooding in case of failure of any unit, to prevent over-dosing and for other purposes.

We wish to express our appreciation to the Board of Selectmen of the town of Billerica and to Mr. Fred O'Hara, Water Superintendent, for their cooperation during the preliminary studies and design of this plant, to Mr. Vernon L. Packard, Public Works Director, for his assistance during the construction of the project, and to Mrs. Barbara E. Hawks, Water Chemist, for her competent operation of the completed plant. We are also indebted to the Beacon Construction Co. for a job well done and to the many suppliers of equipment for their excellent cooperation.

THE PERFORMANCE OF THE BILLERICA WATER TREATMENT PLANT

BY BARBARA E. HAWKES*

[*Read September 17, 1957.*]

The new water treatment plant for Billerica, Mass., was placed in operation for consumption by the town on January 23, 1956. Flexibility and ease of operation have been provided for by the use of several up-to-date features which include: solution chemical feed; two-story sedimentation basins; a sludge collector mechanism, which cleans both floors of the basins and draws the sludge into a sump for removal; an 18-inch depth of coal surmounting the sand on each filter; porous-plate filter bottoms, and many automatic controls.

At the present time the plant is operated 12 hours per day. River water is used almost entirely, with well water treated occasionally when conditions require its use. In extremely cold weather, partial use of the well water at 40° F. has been useful in preventing the formation of ice in the sedimentation basin.

That the plant performs each major step of the treatment process—coagulation, sedimentation, filtration, iron and manganese removal, disinfection, taste and odor removal, and corrosion control—is reflected in the quality of the plant effluent.

Each of the two flocculation basins is divided into three flow-through compartments. This equipment consists of paddles, mounted on and driven by horizontal shafts. The blades of the revolving paddles, or rotors, pass through stationary blades, the stators, which are mounted on the walls of the compartments. This construction permits a uniform distribution of chemicals through the water and the building-up of a readily settleable floc. The flocculation chambers are followed by a pair of two-story sedimentation basins. Floc is allowed to settle on both floors.

Alum is the coagulant employed. Sodium hydroxide is the

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alkali used for pH adjustment in conjunction with the coagulant as well as for pH control of the final effluent.

The water of the Concord River varies rather widely in quality and changes in characteristics from season to season. Coagulation is a complex reaction, and an optimum dosage of alum and caustic soda is determined by jar test. The amount of aluminum sulfate required for coagulation and the relation of this amount to the quantity of caustic soda needed varies, naturally, with the changes in the character of the raw river water. Despite the warmer temperature of the water in summer, considerably larger amounts of coagulant relative to alkali are required, because of the very high color (60-90 ppm) of the river. This period of high coagulant requirement begins early in May and extends through August. With the seasonal increment in temperature, there is a concomitant rise in the natural alkalinity of the raw water. This factor makes it possible to discontinue the usage of caustic soda and thus decrease considerably the aluminum sulfate requirement. Fig. 1 shows the rise in the natural alkalinity in conjunction with temperature increase. Fig. 2 shows alum dosages in relation to the natural alkalinity. Fig. 3 shows the relative amounts of alum and caustic soda used.

The carbon-dioxide concentration of the river water averages about 6.0 ppm, but in the well water this figure varies from 9.0 ppm to 70.0 ppm, with an average of about 40.0 ppm. For this reason alkali is always required in conjunction with alum when well water is used. Aeration is of considerable importance here, since it reduces the carbon-dioxide content by more than half, thus reducing the cost of sodium hydroxide required for its neutralization.

The character of the floc being formed in the mixing basin is carefully watched by the operating personnel, to make sure that effective coagulation is being obtained. Notes of these observations are made in a space provided on the operator's daily charts. Best results are obtained when the pH value of the mixing basin is between 5.8 and 6.2.

Efficient coagulation depends not only upon the usage of the correct relative dosages of chemicals, but also upon the mechanical association of flocculant particles into large settleable masses. The mechanical mixers provide tapered agitation for

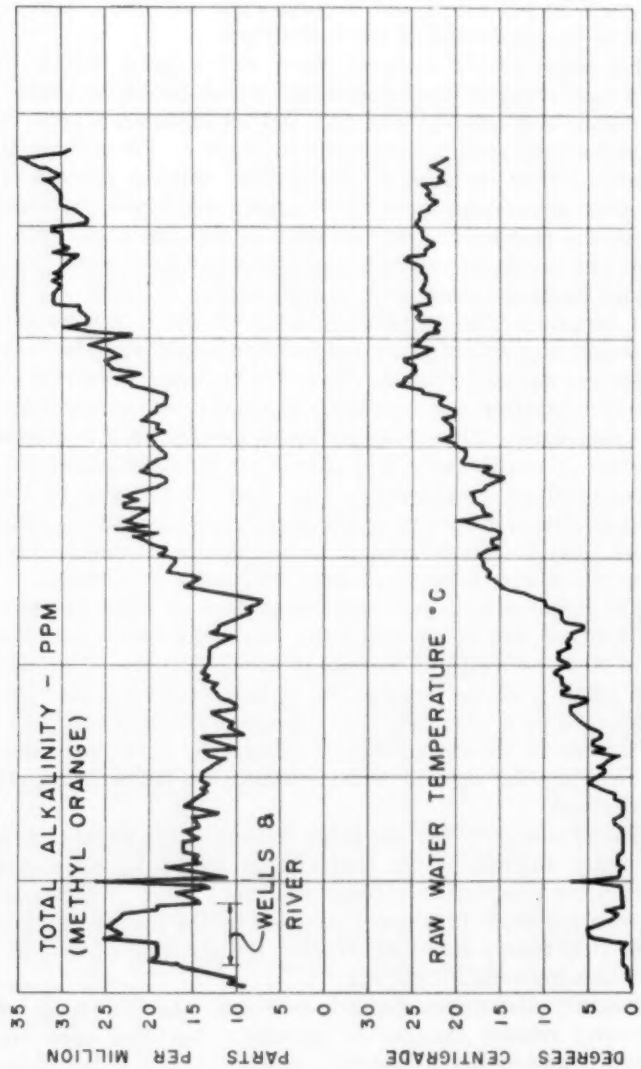

FIG. 1.—WATER TEMPERATURE AND ALKALINITY IN CONCORD RIVER DURING 1957.

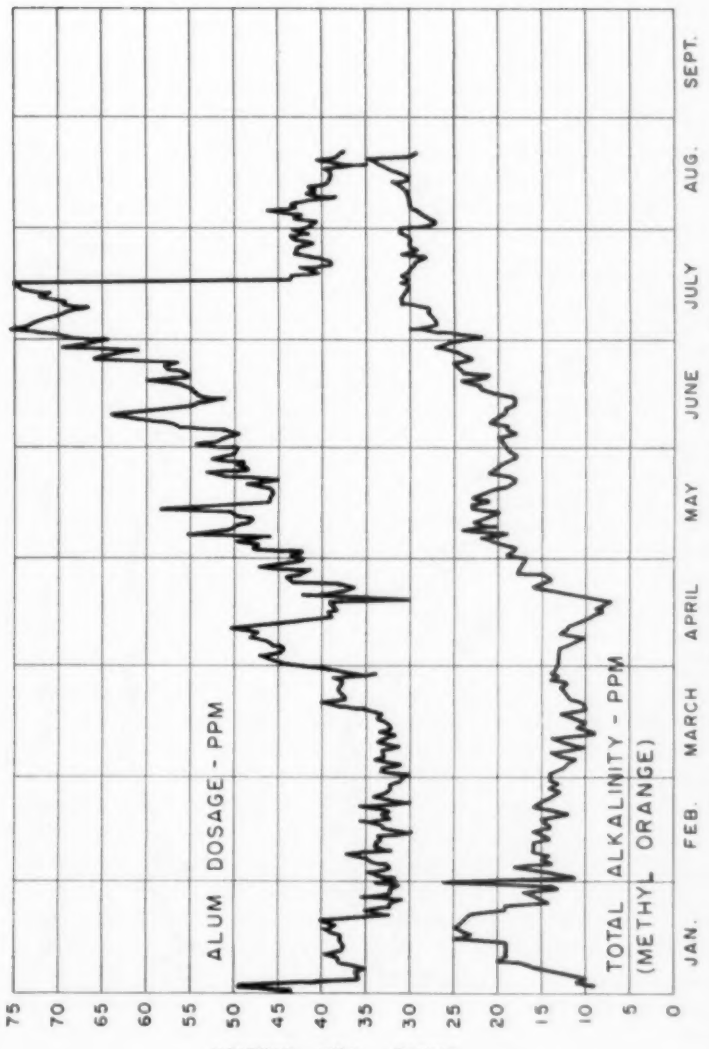

FIG. 2.—ALUM DOSAGE VERSUS ALKALINITY FOR 1957.

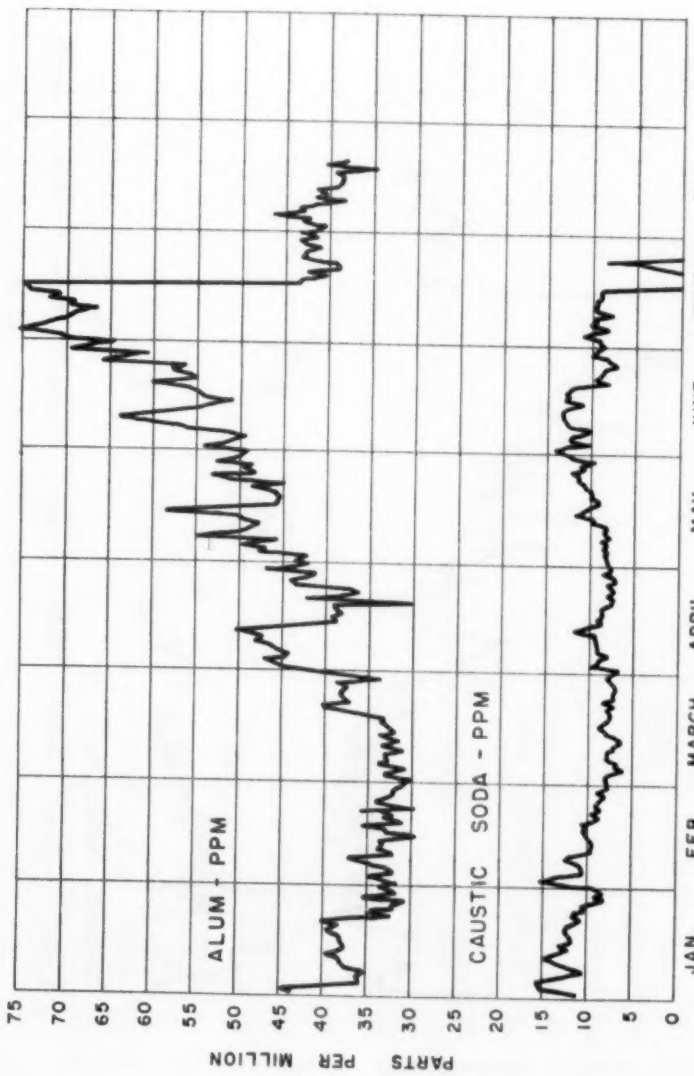

FIG. 3.—RELATIVE DOSAGES OF ALUM AND CAUSTIC SODA FOR 1957.

this purpose. The horizontal shaft in the first compartment is driven separately and at a greater speed than the longitudinal shaft common to the second and third compartments. Most efficient floc formation for various temperatures is obtained with the following speeds on the flocculators: For temperatures from 0° to 18° C., the RPM of the rotor shafts is 6.0 — for compartment one and 1 7/8 for compartments two and three. For temperatures above 18° C. the RPM of the rotor shafts is 3.25 for compartment one and 1.0 — for compartments two and three. These speeds may, of course, be adjusted as needed.

The success of the process of coagulation and sedimentation is reflected in the clarity of the water entering the filters, and in the length of the filter runs. The filter influent bears a color of 5.0 ppm and the carry-over of floc is negligible. Residual aluminum of the plant effluent averages less than 0.20 ppm and the color less than 2.0 ppm.

The effective performance of the rapid sand filters depends both upon proper prior treatment and upon construction of the filter unit. The 18-inch layer of coal on top of each sand filter has been provided to increase the filter runs. Filters are generally operated at the rate of 0.5 mgd per filter. Filter runs over the year average 104 hours or 2.25 mil gal per filter, with a backwash amounting to 2.0% of filtered water. The porous plates have shown no measurable clogging, but were cleaned once with an acid wash.

Deferrization and demanganization of the raw water are accomplished by oxidizing the soluble ferrous and manganous compounds, converting them into insoluble ferric and manganic compounds, which are removable by coagulation and sedimentation, and subsequent filtration. Chlorination is the means by which the soluble ferrous and manganous compounds are converted to ferric and manganic compounds. For both the river and well water, relatively high dosages of chlorine (more than sufficient to exceed the breakpoint) are required for this oxidation. This is especially true in the case of the well water, where iron values are in the vicinity of 2.0 ppm and the manganese 0.6 ppm. The iron content of the river varies widely, with an average of about 0.70 ppm. The average manganese content of the river is about 0.15 ppm, with a maximum of 0.30 ppm. The main

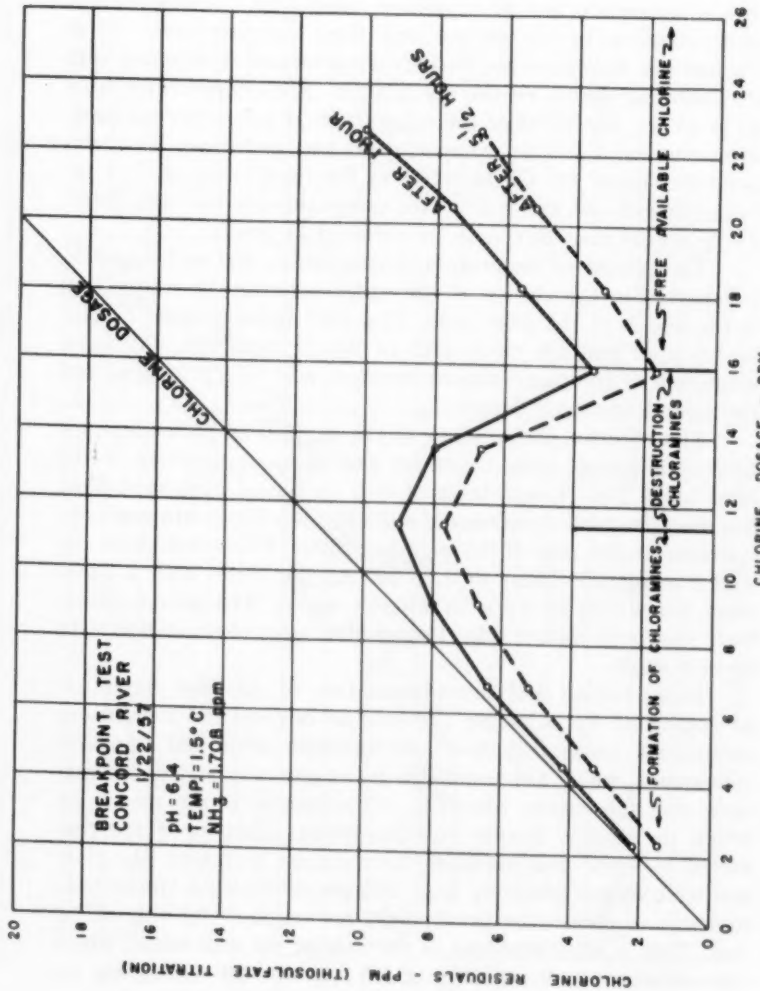

FIG. 4.—TYPICAL BREAKPOINT CURVE FOR CONCORD RIVER WATER.

burden of removal falls upon oxidation by chlorine, coagulation and sedimentation. Manganese is removed with more difficulty than iron, since (1) it oxidizes more slowly and (2) oxidized manganese precipitates so slowly that, even with excellent flocculation, 100% removal is rarely effected. The iron content of the filter influent averages about 0.15 ppm and the manganese about 0.10 ppm. The plant effluent bears an average value of 0.08 ppm for iron (with a maximum of 0.15 ppm) and 0.05 ppm for manganese (with a maximum of 0.15 ppm).

Breakpoint chlorination as practiced at the plant has proven to be extremely advantageous, not only from the standpoint of adequate oxidation of soluble iron and manganese compounds, but also from the standpoint of insuring vigorous disinfection by providing free available-chlorine residuals throughout the treatment process.

Water-sanitation practice recommends a minimum free available-chlorine residual of 0.20 ppm. The Concord River and the wells contain sufficient ammonia to result, upon application of chlorine, in the formation of chloramines (combined available chlorine). Values for free ammonia vary from 0.037 ppm to 2.10 ppm. Obtaining a residual which consists almost entirely of free available chlorine depends upon using chlorine in excess, so that the intermediate chloramines are destroyed. Fig. 4 shows a typical breakpoint curve of the Concord River. During periods of high ammonia content, the maintenance of a 0.20-ppm free available-chlorine residual would require total residuals in the vicinity of 2.00 ppm, if breakpoint chlorination were not being practiced.

Except for periods when offensive odors warrant the application of activated carbon prior to chlorination, the chlorine is applied in the chlorine contact chamber to the previously aerated water in dosages which exceed the breakpoint by 2.0 to 3.0 ppm. By the time the water enters the filters, the chlorine content is usually less than 0.80 ppm. Just ahead of the filters, activated carbon is added, since the raw river water contains at all times at least a slight swampy odor. Because of the adsorptive action of the carbon, filter-effluent chlorine residuals are about 0.10 ppm or less. This procedure permits the deliverance of a practically zero-chlorine-demand water to the filter effluent header. Post-

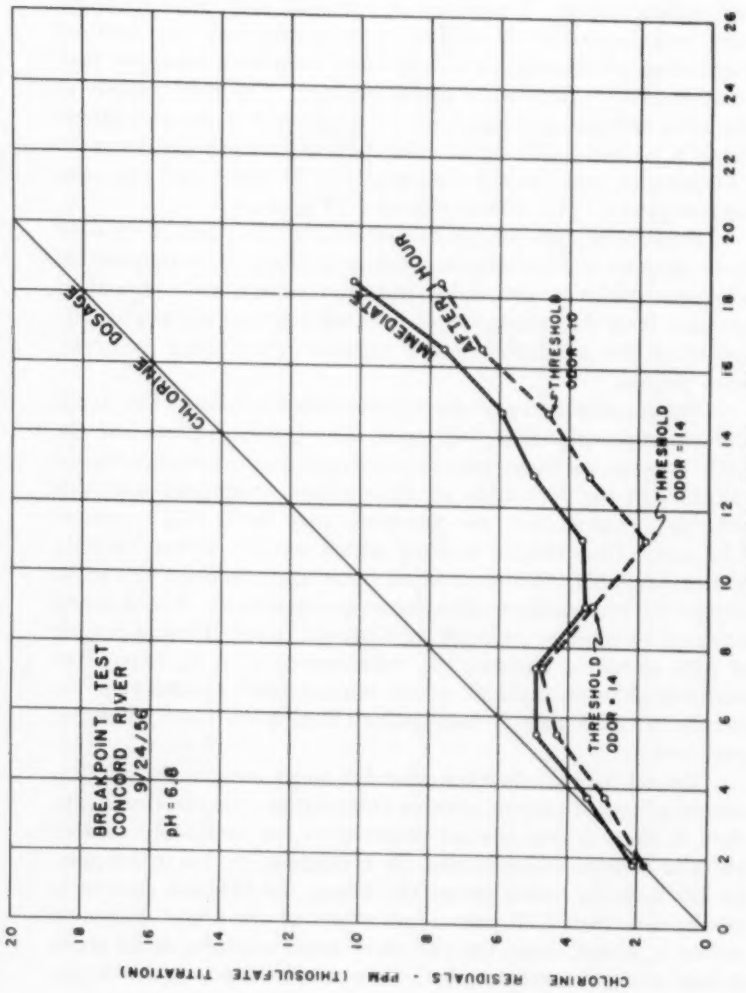

FIG. 5.—RELATIONSHIP BETWEEN CHLORINE DOSAGE AND ODOR.

chlorination dosages at this point are such that they meet the recommendations of the Massachusetts Department of Public Health without the necessity of consumer complaints of "chlorine taste." The plant effluent usually contains a total residual of 0.25 ppm, 80% (or 0.20 ppm) of which is free available chlorine. During 1956, out of 588 samples of which bacteriological examinations were made, there were only 0.75% positive portions from the distribution system. Plant effluent tests showed no positive portions. To date in 1957 no positive portions have been obtained in either the distribution system or the plant effluent.

Chlorine applied to the raw water in amounts which exceed the breakpoint by 2.0 to 3.0 ppm provides only a very slight reduction in odor. Fig. 5 shows a breakpoint curve in which threshold-odor tests were run at several dosage points along the curve.

Removal of odor from the raw water is accomplished by application of activated carbon. The carbon may be added along with the alum and sodium hydroxide as the water enters the flocculation chambers; it may be added to the filter influent; or it may be added to the inlet pipe of the chlorine contact chamber and chlorine solution introduced into the outlet pipe from the chlorine contact chamber. This latter method has been provided to eliminate the possibility that some of the activated carbon surfaces, utilized for adsorption of odorous compounds, might become coated with chlorine, and the efficiency of the carbon might thus be decreased. This method also precludes the formation of odor-producing combinations of chlorine with organic substances in the river water by prior removal of these substances.

Since the Concord River contains at all times at least a faint swampy odor, carbon is used continually, during non-difficult periods, on top of the filters in such quantities as are necessary for odor removal. During fall and winter months 2.0 ppm usually suffice.

With the advent of the increased biological activity and the lower level of the river in the dry summer months, especially August, odors in the river become intense, often quite suddenly. On August 13, 1956, the plant personnel noticed a decided "marshy" odor and taste in the plant effluent. Consumer complaints began to pour in. Since early July, activated carbon had

been applied in dosages of 2.0 to 3.0 ppm to the water as it entered the filters. The point of application was then changed from the filter influent to the coagulation basin, to provide longer contact time. Carbon dosage was raised gradually; 14 ppm did not improve the odor at all. On Sunday, August 19, 1956, in order to dilute the offensively odorous water, the wells were used to maximum capacity (yielding slightly less than half the required water). The marshy odor persisted. Upon return to exclusively river water, the chlorine dosage was reduced to a point just above the breakpoint, and the carbon dosage was increased rapidly, until a sample from the coagulation basin indicated that the carbon was present in great enough quantity to be "outside of" instead of surrounded by floc. When carbon and coagulant are dosed at the same point, the adsorptive ability of the carbon will be hampered if carbon is used only in such quantities as to provide "seeding," resulting in a carbon nucleus surrounded by flocculant particles. When a carbon dosage of 86.3 ppm was reached, the odor was removed, and one consumer called specifically to notify the chemist of the "good quality" of the water.

In the summer of 1957, points of application of carbon and chlorine were reversed. Odor removal was effected with dosages of 65.0 ppm. Although a strict comparison with a previous year cannot be made with certainty, this would seem to indicate a saving of roughly 20.0 ppm on activated carbon, which represents approximately $19.00 per day.

Many of the Billerica pipelines have over the years become badly corroded on the interior, and rust deposits resulting from this corrosion have substantially decreased the flow capacity and have previously been the cause of numerous and severe complaints from consumers. A long-range program for the cleaning of the distribution system was begun in the summer of 1956 in the northern part of the town. After the completion of this cleaning, residents in this part of town experienced red-water troubles. A flushing program proved to give only temporary relief. Bleeds were installed on several hydrants but had to be removed because of icing conditions. Analyses of samples from this section of town showed an iron content of 10.0 ppm and a color of over 100.0 ppm.

A systematic study was begun on samples collected from six

stations, all consumers' taps. The pH of the plant effluent prior to this cleaning had been maintained at 9.5. It was decided that control of this condition should be attempted by upward adjustment of the pH of the plant effluent to a minimum value of 10.0. Subsequent to this increase in pH the iron content decreased steadily at all points. Satisfactory results have been obtained since that time. Iron values of the water from the distribution system are typically 0.10 ppm and the color 5.0 ppm or less. Occasionally high iron concentrations are experienced on dead-end lines or after a heavy and rapid draw, such as from a fire. The results obtained from this systematic study indicate that a pH of 10.0 will successfully abate red-water troubles everywhere, except for occasional difficulties with dead-end lines. It is hoped to eliminate the offending dead ends by means of loop installations.

Before the completion of the new water-treatment plant, the town's water supply was inadequate in capacity and of inferior quality, due to the high concentrations of iron and manganese. The start of operation of this new plant has enabled the town of Billerica to meet the ever increasing demands of the rapidly growing community for water from the standpoint of quality as well as quantity.

Since the start of the new plant, 307 new services were added in 1956 and 178 to date in 1957. At the start of operation of the plant, the average daily consumption for the town was about 550,000 gal per day. The peak consumption for one day in 1956, reached in August, was over 1.4 mil gal. The average daily consumption for the town is now almost 900,000 gal. In 1957 the peak consumption for one day, reached in July, was 1.79 mil gal.

The town's water supply is now of excellent quality physically, bacteriologically, and chemically. It is non-corrosive, with an iron and manganese content which falls well below the limit allowed by the U. S. Public Health Service Drinking Water Standards.

We should like to express our appreciation to Mr. William Kerivan, Chief Operator, for his excellent mechanical maintenance of the treatment-plant equipment, and to Mr. Lawrence Bevis, Operator, for his fine care of the plant.

MEMOIR OF CHARLES W. SHERMAN

Charles W. Sherman, Honorary Member and Past President, died at a Cambridge hospital on January 17, 1958, after a short illness.

Mr. Sherman was born in Kingston, Mass., on September 26, 1870, a descendant of the earliest settlers in New England. He had lived in Belmont the last 58 years of his life.

He was graduated from M.I.T. in 1890 with a B.S. degree and later from Cornell University with an M.C.E. degree. From 1895 to 1904 he was Assistant Engineer and Division Engineer with the Boston Water Works.

In 1904 he became associated with Leonard Metcalf and continued as principal engineer with Metcalf & Eddy from 1907 until 1913, when he became a partner. In 1938 he retired from this engineering firm.

He was a Water Commissioner in Belmont for 24 years, being Chairman of the Board for some seven years of that time. He had been President of the Belmont Savings Bank and a Trustee of the Merchants Cooperative Bank of Boston. He had been a member of numerous professional organizations, including the A.S.C.E., B.S.C.E., and A.W.W.A. He was active in the Masonic fraternity and historical organizations and was well versed in the early history of Massachusetts, particularly that of the Revolutionary period

His professional activities were largely in the water-works field, including hydrology, design, valuations, and maintenance of water-works properties. He was the author of many technical papers and was the recipient of the Dexter Brackett Medal of the Association for 1922 for his paper, "The Proper Term for Which Water Works Bonds Should Run."

He was a most loyal member of the Association, serving on many important committees. From 1899 to 1900 he was Junior Editor of the JOURNAL and Editor from 1901 to 1908. He joined the Association in 1897, was President in 1921, and was elected an Honorary Member in 1931.

Most of Charles Sherman's contemporaries in the Association have passed away, but those who do remember him in his active days can recall fondly his genial and friendly presence, and the ease and fluency with which he joined in the discussions of papers given before the Association.

Mr. Sherman leaves two sons, John and Richard, and two brothers, Edward and Herbert. He was twice married, both of his wives predeceasing him by many years.

E. SHERMAN CHASE

PROCEEDINGS

November 1957 Meeting

Hotel Statler, Boston, Mass.

Thursday, November 21, 1957

President George G. Bogren in the Chair.

The President announced the death on November 3, 1957, of Linn H. Enslow, Editor of *Water & Sewage Works*, who had been a member of the Association since 1931.

Secretary Knox announced the election of the following to membership in the Association:

Members:

Fozi M. Cahaly, Director, Fay, Spofford & Thorndike, Boston, Mass.; Sanford J. Russell, Sales Representative, Red Hed Manufacturing Co., Boston, Mass.; Bradford S. Thomas, Superintendent of Streets, Wareham, Mass.; Lee Marc G. Wolman, Civil Engineer, Charles T. Main, Inc., Boston, Mass.; Russell H. Babcock, Engineer, Foxboro Co., Foxborough, Mass.; Howard C. Morse, Superintendent, Water Department, Foxborough, Mass.

Associate:

Holyoke Machine Co., Holyoke, Mass.

An illustrated talk on "Side-Lights on Alaskan Construction" was given by Prof. Edward S. Brown, Jr., Thayer School of Engineering, Dartmouth College, Hanover, N. H.

A paper on "Modernizing the Water Department, Fire District No. 1, South Hadley, Mass.," was read by George H. McDonnell, Chief Engineer, Tighe & Bond, Inc., Holyoke, Mass.

A film, "The Challenge of Outer Space," was shown by courtesy of the U. S. Department of Defense.

DECEMBER 1957 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, DECEMBER 19, 1957

President George G. Bogren in the Chair.

Secretary Knox announced the election of the following to membership in the Association:

Members:

Francis P. Allen, Jr., Chemical Sales and Engineering, with E. & F. King & Co., Norwood, Mass.; Ramchandra S. Ambekar, Lecturer in Chemistry, Government Polytechnic, Ahmedabad, India; Gordon N. Ells, Manager, Hampton Water Works Co., Hampton, N. H.; Lyman R. Howard, Superintendent, Water Works, East Bridgewater, Mass.

Associate:

Scott Associates, Inc., Clinton, Mass.

A paper on "New Ground-Water Supply for Augusta Water District" was read by Sidney S. Anthony, Superintendent, Augusta Water District, Augusta, Me.

A paper on "Wakefield's Water Emergency and Solution" was read by George R. Winters, Director, Public Works, Wakefield, Mass.

A paper on "Pressure Tool Cleaning of Water Mains" was read by Raymond F. Bahr, Jr., Flexible, Inc., and New England Pipe Cleaning Co., Cheshire, Conn.

JANUARY 1958 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, JANUARY 16, 1958

President George G. Bogren in the Chair.

PRESIDENT BOGREN. Gentlemen it is my sad duty to notify you of the death of two of our members since our last meeting. Will you kindly stand for a moment in respect to them?

[*The members stand.*]

The first is James W. Blackmer of Beverly, who passed away on January 10. He was 89 years old and had been a member of this Association for 59 years. He was formerly Commissioner of Public Works at Beverly, Mass.

On January 14 Leander G. Smith passed away. He was Superintendent and Treasurer of the Kennebunk Water District, Kennebunk, Me.

We shall now hear from our Secretary, Mr. Knox, on business that was transacted this morning.

SECRETARY KNOX. I am pleased to announce that we elected four new members this morning:

Charles H. Connors, Engineer, Coffin and Richardson, Inc., Boston, Mass.; Douglas H. Perkins, Foreman, Water Department, Seabrook, N. H.; Alphonse L. Savignac, Superintendent and Town Engineer, Amesbury, Mass.; Werner Stumm, Assistant Professor of Sanitary Chemistry, Harvard University, Cambridge, Mass.

Our membership today is 1,113.

I also wish to announce that there has been an urgent request for copies of the JOURNAL—the June, 1941, issue. If anyone has an extra copy and would like to make it available, we should appreciate it very much.

PRESIDENT BOGREN. In recent years, gentlemen, there was added in the field of tanks the use of prestressed, preload con-

crete, and this afternoon we are going to hear from two speakers on that subject.

A paper on "Preload Water Tanks" was read by J. J. Closner, Vice-President, The Preload Co., Inc., New York, N. Y.

A paper on "Prestressed Water Tanks" was read by Francis X. Crowley, Vice-President, National Gunite Corp., Boston, Mass.

A film, "Conversion of the Cochituate Aqueduct to a High Level Sewer," with commentary by U. M. Schiavone, City Engineer, Newton, Mass., was explained by Edmund Bolduc.

AWWA C203–57

(*Formerly* C203 & C204)

American Water Works Association

AWWA Standard

for

COAL-TAR ENAMEL PROTECTIVE COATINGS FOR STEEL WATER PIPE

The American Water Works Association has adopted and promulgates this "Standard for Coal-Tar Enamel Protective Coatings for Steel Water Pipe." It is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of use of the material herein described for any installation must be subjected to review by the engineer responsible for the construction in the particular locality concerned.

First Edition approved Apr. 25, 1940; revised 1949, 1950, 1951, 1955.
Second Edition approved Mar. 27, 1957

Second Printing, October 1957

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

Latest Revisions to C203 (Formerly C203 & C204)

On Mar. 27, 1957, the AWWA Board of Directors approved the publication of a new edition (the second) of AWWA C203, combining into one document the former AWWA C203 (applicable to pipe of 30 in. and over) and C204 (applicable to pipe up to 30 in.). The resulting revisions affect every section of the standard, to a greater or lesser extent. All printings of the First Edition are obsolete.

Designation. The former designation, "C203–55," has been changed to "C203–57." The C204 designation has been eliminated.

This printing contains all the revisions and changes summarized above.

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as part of the July 1957 Journal AWWA

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C. B. HARDY

Acknowledgment is made and appreciation expressed to Harry Hayes, Assistant Sanitary Engineer, Department of Water and Power, Los Angeles, and to the Manufacturers Technical Advisory Committee to AWWA Committee 8310 D, for their assistance and cooperation in the preparation of this standard.

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AWWA Standard for

Coal-Tar Enamel Protective Coatings for Steel Water Pipe

Section 1—General

Sec. 1.1—Purpose

These specifications cover the material and application requirements for coal-tar enamel protective coatings for steel water pipe to be installed under normal or average construction conditions in any soils, or aboveground.

An Appendix has been added to these specifications to provide additional exterior protective measures for steel water pipe to be installed under unusual construction conditions—such as submarine lines, casing pipe, and river crossings—and in exceptionally rocky areas.

The purchaser, when inviting bids, shall specify his requirements for protective coating by referring to the designation of these specifications and to the section and subdivision of the Appendix for the type of additional protection if such be required. In addition, the purchaser shall supply certain detailed information covering each individual contract in accordance with Sec. 1.3 of these specifications.

Sec. 1.2—Scope

Corrosion protection as provided under these specifications is as follows:

1.2.1. *For the inside of all pipe,* a coat of coal-tar primer followed by a hot coat of coal-tar enamel applied either by manual or mechanical means.

1.2.2. *For the outside of all pipe less than 30 in. in diameter to be placed underground,* a coat of coal-tar primer followed by a hot coat of coal-tar enamel into which shall be bonded a single layer of asbestos felt wrap, and finished with one coat of water-resistant whitewash or a single wrap of kraft paper as outlined in the Appendix.

1.2.3. *For the outside of all pipe 30 in. in diameter and larger to be placed underground,* a coat of coal-tar primer followed by a hot coat of coal-tar enamel and one coat of water-resistant whitewash. If the purchaser desires a layer of asbestos felt wrap as outlined in the Appendix, he shall so state in the call for bids.

1.2.4. *For the outside of all pipe to be placed aboveground* exposed to the weather, two coats of synthetic red lead primer (or one coat of synthetic red lead primer and one coat of synthetic white enamel) and one coat of aluminum paint.

1.2.5. *For the outside of all pipe to be placed aboveground and exposed to more corrosive than normal conditions,* such as in coastal or industrial areas, one coat of coal-tar primer (if blasted before erection), one coat of heavy-bodied coal-tar coating (cold applied), one coat of heavy-bodied coal-tar emulsion, and one coat of aluminum paint. The coat of coal-tar primer is to be eliminated if the surfaces are blasted after erection.

Sec. 1.3—Supplementary Details Which Shall Be Supplied by the Purchaser

1.3.1. Where a steel pipeline is to be laid under conditions ordinarily found in water transmission and distri-

bution systems, reference to the specifications shall be as follows:

(1) *For pipe less than 30 in. in diameter:*

The interior surface of all steel pipe shall be cleaned, primed, and lined with coal-tar enamel, and the exterior shall be cleaned, primed, and coated with coal-tar enamel with a *bonded* asbestos felt wrapper. All such materials and application shall be in accordance with American Water Works Association Specifications C203, together with Sec. A1.2 and A3.1 of the Appendix of those specifications.

(2) *For pipe 30 in. in diameter and over:*

The interior surface of all steel pipe shall be cleaned, primed, and lined with coal-tar enamel, and the exterior shall be cleaned, primed, and coated with coal-tar enamel. All such materials and application shall be in accordance with American Water Works Association Specifications C203.

1.3.2. If additional exterior protection is desired, in the opinion of the engineer, because of extreme soil conditions or on submarine lines, river crossings, etc., the engineer shall designate in his specifications one of the alternate types of exterior protection, provided in the Appendix. The following *example* illustrates how such specifications should be written:

The interior surface of all steel pipe shall be cleaned, primed, and lined with coal-tar enamel, and the exterior shall be cleaned, primed, and coated with coal-tar enamel and wrapped with bonded double asbestos felt wrappers. All such materials and application shall be in accordance with American Water Works Association Specifications C203, together with Section (A1.3 *) of the Appendix of those specifications.

1.3.3. In purchasing protection for steel water pipe, the purchaser shall make supplementary specific statements in his specifications regarding the following:

(1) *Project.* Diameter, length, and location of pipeline, including maps and drawings necessary to show all details of line within the scope of the contract.

(2) *Temperatures.* Range of atmospheric temperatures to which the pipe may be subjected during, or subsequent to, installation.

(3) *Exterior protection—underground.* Length of line to be protected for underground service.

(4) *Exterior protection—aboveground.* Length of line to be erected aboveground for normal atmospheric service; and length of line to be erected aboveground where more corrosive conditions exist.

(5) *Contractor's samples.* Requests for contractor's samples in accordance with Sec. 2.3 of these specifications.

(6) *Materials.* When "corrosion protection" outlined here is to be done by force account or by separate contract, specify:

a. Quantity of coal-tar primer.

b. Quantity and type or types of coal-tar enamel.

c. Quantity of asbestos felt.

d. Quantity of fibrous glass mat.

e. Quantity of paint or exposed steel surfaces:

(i) Synthetic red lead primer.
(ii) Synthetic white enamel.
(iii) Aluminum bronzing liquid.
(iv) Aluminum pigment.
(v) Cold-applied coal-tar coating.
(vi) Cold-applied coal-tar emulsion.

Sec. 1.4—Definitions

Under these specifications the following definitions will apply:

1.4.1. *Purchaser.* The word "purchaser" shall mean the person, firm, corporation, or governmental subdivision entering into a contract or agreement for the purchase of any materials and/or any work to be performed under these specifications.

* Purchaser shall specify the type of exterior protection set forth in the Appendix.

1.4.2. *Contractor.* The word "contractor" shall mean the person, firm, or corporation executing the contract or agreement with the purchaser to furnish any material and/or to perform any work under these specifications.

1.4.3. *Inspector.* The word "inspector" shall mean the inspector or engineer employed by the purchaser and acting as his representative; their respective assistants properly authorized and limited to the particular duties assigned to them; or the purchaser, himself, acting as his own engineer.

1.4.4. *Blasting.* The word "blasting" shall mean blasting with standard sand-blasting sand or steel grit to clean and thoroughly remove all rust and mill scale from the steel.

1.4.5. *Centrifugal casting.* The words "centrifugal casting" shall mean the process of applying coal-tar enamel to the inside surface of pipe whereby molten coal-tar enamel introduced into the pipe is spread on the surface of the pipe and held thereon by the centrifugal force developed by rotating the pipe about its longitudinal axis until the coal-tar enamel has cooled and solidified and become bonded to the pipe.

Sec. 1.5—Inspection and Testing

1.5.1. The entire procedure of applying the protective coating material as herein specified will be rigidly inspected from the time the bare pipe is received until the coated pipe is laid in the ground and backfilled and/or installation of surface pipe is completed. Such inspection shall not relieve the contractor of his responsibility to furnish material and perform work in accordance with these specifications.

1.5.2. All coating work to be acceptable must be applied in the presence of the inspector, and all such work done in his absence will be subject to rejection unless the continuance of the work during his absence is specifically allowed by the inspector. If at any time it is found that the procedure of applying the protective coating material is not in accordance with these specifications, all such coating work may be rejected.

1.5.3. Prior to approval of contractor's material, samples of material submitted by the contractor will be tested by the purchaser and if any sample is found not to conform to these specifications, material represented by such sample will be rejected. If samples of contractor's approved materials are found not to conform to the specifications, all such material will be rejected.

1.5.4. Samples submitted to the purchaser will be tested in the purchaser's laboratory or in a responsible commercial laboratory designated by the purchaser.

1.5.5. The expense of testing of all samples of material originally offered by the contractor will be borne by the purchaser; the expense of all subsequent tests due to failure of samples of materials originally offered to comply with these specifications will be charged to the contractor.

Sec. 1.6—Access for Inspector

The inspector shall have free access to those parts of all plants that are concerned with the furnishing of materials or the performance of work under these specifications.

Sec. 1.7—Facilities for Inspector

The contractor shall furnish the inspector reasonable facilities and space without charge for the inspection, testing, and obtaining of such information as he desires respecting the character of material used and the progress and manner of the work.

Sec. 1.8—Material and Workmanship

All material furnished by the contractor shall be of the specified quality. All work shall be done in a thorough workmanlike manner. The entire operation of priming the pipe and heating and applying the coal-tar enamel coatings shall be performed under the supervision of and by experienced men skilled in the application of coal-tar enamel.

Sec. 1.9—Equipment

The contractor's equipment for all blasting, priming, enameling, and painting shall be designed and manufactured and shall be in such condition as to permit applicators to follow the procedure and obtain results prescribed in these specifications.

Sec. 1.10—Packaging

All coal-tar enamel and coal-tar primer and wraps purchased or used under these specifications shall be packaged in suitable and approved containers. The containers shall be plainly marked with the name of the manufacturer, type of material, and batch or lot number.

Section 2—Material Specifications

Sec. 2.1—Coal-Tar Primer

All coal-tar primer to be used under these specifications shall comply with the following:

2.1.1. The primer shall consist of processed coal-tar pitch and refined coal-tar oils only, suitably blended to produce a liquid coating which may be applied cold by brushing or spraying and which will produce an effective bond between the metal and subsequent coating of coal-tar enamel. Primer shall contain no benzol or other toxic or highly volatile solvents and no added pigments or inert fillers, or other substances, and shall show no tendency to settle out in the container.

2.1.2. The primer shall have good spraying and brushing properties and a minimum tendency to produce bubbles during application. The primer shall dry hard to the touch when applied as recommended.

Sec. 2.2—Coal-Tar Enamel

The type of enamel used shall be AWWA coal-tar enamel. This enamel shall be composed of a specially processed coal-tar pitch combined with an inert mineral filler. No asphalt of either petroleum or natural base shall be acceptable as part of the ingredients. The enamel shall have the characteristics shown in Table 1.

Sec. 2.3—Contractor's Samples and Detailed Information

2.3.1. When specified by the purchaser, the contractor shall submit to the purchaser for testing, prior to any work under these specifications, a 50-lb sample of the coal-tar enamel and a 1-qt sample of the coal-tar primer he proposes to furnish. Samples shall be taken from a production run of the manufacturer's plant. Samples shall be identified by batch or lot numbers. Contractor shall submit with the samples a certified copy of results of tests made by the manufacturer covering the physical and performance characteristics of the samples. This certificate shall indicate the coverage rate of the

TABLE 1

Characteristics of AWWA Coal-Tar Enamel

Test	Minimum	Maximum
Softening point—ASTM D36-26	220°F	—
Filler (ash)—ASTM D271-48	25%	35%
Fineness filler, through 200 mesh—ASTM D546-41	90%	—
Specific gravity at 25°C—ASTM D71-52	1.40	1.60
* Penetration—ASTM D5-52		
At 77° F—100-g weight—5 sec	10	20
At 115°F—50-g weight—5 sec	15	55
High-temperature test—at 160°F (sag)—AWWA C203, Sec. 2.4.4(1)	—	$\frac{1}{32}$ in.
Low-temperature test—at −20°F (cracking)—AWWA C203, Sec. 2.4.4(2)	—	none
† Deflection test (initial heating)—AWWA C203, Sec. 2.4.4(3)		
Initial crack	0.8 in.	—
Disbonded area	—	3.0 sq in.
† Deflection test (after heating)—AWWA C203, Sec. 2.4.4(4)		
Initial crack	0.6 in.	—
Disbonded area	—	5.0 sq in.
† Impact test—at 77°F—650-g ball, 8-ft drop—AWWA C203, Sec. 2.4.4(6)		
Direct impact—disbonded area	—	10.0 sq in.
Indirect impact—disbonded area	—	2.0 sq in.
Peel test—AWWA C203, Sec. 2.4.4(5)	no peeling	

* For anticipated minimum temperature exposures between 20° and −20°F, use enamels with penetration of 15 to 20 at 77°F.

† Choice of bond testing methods A or B by deflection (before heating), by deflection (after heating), or by impact shall depend upon laboratory equipment available.

primer in grams per square foot, the application temperature of the enamel, and the method of application of the enamel to the test plates.

2.3.2. Samples submitted to the purchaser will be tested in the purchaser's laboratory or in a responsible commercial laboratory designated by the purchaser.

2.3.3. The expense of testing of all samples of material supplied by the contractor will be borne by the purchaser.

2.3.4. After the contractor has obtained approval from the purchaser for the coal-tar enamel and coal-tar primer he proposes to furnish, the contractor shall submit the coating manufacturer's detailed specifications for the coal-tar enamel and coal-tar primer supplied for the project, with instructions for the handling and application of the material; this information shall include:

(1) Method of application of primer and coverage in square feet per gallon.

(2) Minimum and maximum drying time of the primer before application of enamel.

(3) Application temperature of enamel.

(4) Maximum allowable temperature to which enamel may be heated.

(5) Maximum time enamel may be held in heating kettles at application temperature.

2.3.5. Contractor will be required to furnish the purchaser with a certified copy of results of tests made by the manufacturer covering physical and performance characteristics of each batch of enamel and primer to be sup-

plied under these specifications. When requested by the purchaser, the contractor shall furnish or allow the purchaser to collect samples of the material representative of each batch of enamel and/or primer. Certified test reports and samples furnished by the contractor shall be properly identified to each batch of enamel and/or primer.

Sec. 2.4—Test Procedure for Primer and Enamels

Tests to determine physical characteristics of enamel and primer furnished by the contractor or collected by the purchaser shall be in accordance with the American Society for Testing Materials Standard Designations as indicated in Sec. 2.2 (Table 1) of these specifications. The preparation of test specimens and the testing for performance characteristics by methods other than ASTM procedures shall be in accordance with the following procedure:

2.4.1. *Preparation of test plates.* All performance tests shall be made on steel plates free of all oil and grease. One side of each plate shall be blasted to a uniform steel gray surface, completely removing rust, mill scale, and all other foreign matter. For blasting, a sharp, dry sand having a minimum of 50 per cent retained on a 60-mesh screen or a No. 50 steel grit shall be used with an air pressure of not less than 75 psi.

2.4.2. *Priming test plates.* All test plates shall be freshly prepared as specified in Section 2.4.1 and shall be primed using 5.0–9.0 g per square foot.* The primer shall be applied with a new, clean, flat bristle brush of 1-in. width. Plates shall be primed and dried while lying horizontally in a well ventilated room under the following conditions:

(1) Temperature— minimum 70°F, maximum 90°F.

(2) Relative humidity—maximum 60 per cent.

(3) Enamel shall be applied after 16 hr, but not later than 72 hr after the primer has been applied.

2.4.3. *Preparation of enamel for testing.* Thirty pounds of enamel broken into pieces approximately 4 in. in maximum dimension shall be rapidly melted over a large gas burner in a metal container of uniform cross section not less than 8 in. nor more than 12 in. in diameter. Immediately upon reaching the specified application temperature, the enamel shall be applied to the primed test plates required for high-temperature and low-temperature performance, Method A or Method B; deflection test (initial heating), Method A; peel test; and impact test, Method B. The remaining enamel in the container, which shall be not less than 20 lb, shall be maintained at the recommended application temperature for a 2-hr period. The enamel shall be stirred with a metal bar at intervals of 15 min during the heating period. A $\frac{1}{4}$-in. steel plate shall be interposed between the container and gas flame to avoid superheating. After the 2-hr heating period, this enamel shall be applied to the test plates required for "Deflection test (after 2-hr heating)," Method A. The application temperatures and method of application shall be as recommended by the coating manufacturer. The enamel shall be applied to a thickness of $\frac{2}{32}$ to $\frac{3}{32}$ in. for all test plates.

2.4.4. *Testing procedure.* Depending on the laboratory equipment avail-

* The testing laboratory shall follow specific recommendations of the manufacturer for coverage rate of primer to be applied to test plates.

able, either Method A or Method B shall be used for the following tests:

(1) *High-temperature test:*

a. Method A. Two 12 × 4 × $\frac{3}{16}$-in. plates prepared as above, on which shall be scribed three lines at 3-in. intervals across the enamel surface, shall be tested as directed under "Procedure."

b. Method B. Two 12 × 12 × $\frac{1}{4}$-in. plates prepared as above with a $\frac{1}{2}$-in. uncoated border left around the four edges of the plates, on which shall be scribed lines 1 in. apart across the face of the enamel and continued on the uncoated surface of the plate to the edges, shall be tested as directed under "Procedure."

c. Procedure. The plates as prepared for Method A or Method B shall be stored in a vertical position in a chamber the temperature of which shall be controlled for 24 hr at 160°F. At the end of this period the plates shall be removed and cooled to room temperature, and the average sag of the lines on the two plates shall be recorded as sag of the enamel.

(2) *Low-temperature test.* After the two plates, prepared as in Method A or Method B, have been used in the above test, they shall be placed in a chamber the temperature of which shall be controlled for a 6-hr period at −20°F. At the end of this period the plates shall be removed and allowed to reach room temperature, then examined for evidence of cracking and/or disbonding of the enamel.

(3) *Deflection test (initial heating).* Four plates, 10 × 4 × $\frac{1}{16}$ in., prepared as above for testing under Method A, shall be stored in a chamber the temperature of which shall be controlled at 40°F. After a 6-hr period the plates shall be tested for deflection on equipment in this chamber by supporting the plates on $\frac{1}{2}$-in. radius knife edges which are spaced on 9$\frac{1}{2}$-in. centers. The deflecting load shall be centrally applied across the plate by a $\frac{1}{2}$-in. radius mandrel at the rate of 1 in. per minute (to produce tension in the enamel) until cracking occurs, as indicated by an electrical holiday detector. The deflection producing the initial cracking shall be recorded, and the deflection shall then be continued to a maximum distance of 1$\frac{1}{2}$ in. The specimen shall then be removed from the machine for examination. All disbonded enamel shall be removed from the plate, and the area of metal exposed on the four plates shall be measured. The average results of initial cracking and disbonded area shall be recorded.

(4) *Deflection test (after 2-hr heating).* Four plates, 10 × 4 × $\frac{1}{16}$ in., prepared as above for testing under Method A shall be used in this test. The procedure shall be the same as described in Sec. 2.4.4(3) above, and the average results of initial cracking and disbonded area shall be recorded.

(5) *Peel test.* Two plates, 12 × 12 × $\frac{1}{4}$ in., shall be prepared as above for testing enamel. After the application of enamel the plates shall be allowed to cool to room temperature. (Tolerance of ± 2°F will be allowed on all temperature requirements listed below.)

a. Bond, initial. One test plate shall be tested directly. The condition of bond shall be tested over a temperature range of 80°–160°F at successive intervals of 20°F—that is, 80°, 100°, 120°, 140°, 160°F. The test shall be made at the temperatures indicated by immersing the plates for a period of approximately $\frac{1}{2}$ hr in a water bath maintained at the selected temperature. At the end of each of these periods the plate shall be removed from the bath

and immediately tested for peel. This shall be done as follows: With a knife edge, cut two parallel lines through the enamel approximately $\frac{3}{4}$ in. apart and approximately 4 in. in length. With the edge of the knife blade, cut under the enamel strip at one end and loosen the enamel from the plate the full width of the strip for about $\frac{1}{2}$ in. Place the knife blade under the loosened end, and with a firm grip apply a slow, steady pull upward on the enamel strip. Adhesion of the enamel at each of the indicated test temperatures, to the extent of preventing peeling, stripping, or lifting of not more than $\frac{1}{8}$ in., shall be recorded as no peeling. The use of the water bath for the 80°F test may be omitted when the room temperature closely approximates 80°F.

b. Bond, after 72 hr at 160°F. The second test plate shall be stored in a horizontal position, with the enameled side up, in a chamber the temperature of which shall be controlled for 72 hr at 160°F. At the end of this period the plate shall be removed and cooled to room temperature and tested for condition of bond over a temperature range of 80°–160°F as above.

(6) *Impact test.* The $12 \times 12 \times \frac{7}{64}$-in. plates, prepared as above and used under test procedures in Sec. 2.4.4(1) and 2.4.4(2) under Method B, shall be allowed to reach room temperature and then shall be immersed in a water bath held at a uniform temperature of 77°F for a period of at least 1 hr before testing. Each plate shall be removed from the water bath, dried with a soft clean cloth, and immediately subjected to the impact test.

a. Direct impact. Each plate shall be supported on the true plane surface of a block of wood. A 650-g steel ball with a well polished spherical surface shall be dropped from a height 8 ft above the surface of the plate when testing enamel. The ball shall be dropped so as to strike the enamel at a point at least 4 in. from any edge of the plate. After one such impact, the enamel shall be examined for evidence of shattering and loosening from the plate.

b. Indirect impact. After being subjected to direct impact, plates shall be placed with the coated face down on a wooden block through which a $3\frac{1}{2}$-in. diameter hole has been cut. The same ball shall then be dropped from a height of 8 ft above the surface of the plate, so as to strike the steel plate at a point over the center of the hole in the wooden support block. The point of impact shall be at least 4 in. from any edge of the plate and shall be at least 3 in. from the point of direct impact. After one such impact, the enamel shall be examined for evidence of shattering and loosening of the coating. Coating that has been knocked off the plate by the impact of the steel ball shall be considered as shattered coating. Loose coating is coating that has not been shattered but can be easily and readily removed from the plate by the fingers or, with very little force, by the use of a knife blade or similar instrument. After removal, the area of loosened coating shall be determined.

Sec. 2.5—Whitewash Formula

All whitewash to be used shall be mixed as follows:

2.5.1. *Ingredients:*

50 gal water.
1 gal boiled linseed oil.
150 lb processed quicklime.
10 lb salt.

2.5.2. *Mixture.* Lime and oil shall be slowly added simultaneously to the water and mixed thoroughly. The

mixture shall be allowed to stand for not less than 3 days before it is used.

Sec. 2.6—Synthetic Red Lead Primer

The paint to be used for the first and second exterior coats on steel structures erected aboveground shall comply with the following:

2.6.1. The red lead primer shall be a ready mixed paint composed of red lead pigment and synthetic-resin vehicle well ground together to produce a liquid coating which may be applied by brushing or spraying and which will dry rapidly and provide a suitable bond between the metal and subsequent coating of paint. The primer shall contain no benzol or other toxic solvent and shall show no tendency to jell or liver in the container.

2.6.2. The primer shall possess the following physical characteristics:

(1) Viscosity at 77°F—30–50 sec Gardner Mobilometer (Solid Plunger) 150-g total weight, 10-cm drop.

(2) Weight per gallon—20–22 lb (ASTM D287–53T).

(3) Dry red lead (97 per cent Pb_3O_4)—minimum 70 per cent by weight.

(4) Varnish vehicle (synthetic-resin type)—maximum 30 per cent by weight.

2.6.3. The vehicle shall be a synthetic-resin varnish consisting of either an alkyd or phenol-formaldehyde resin with the necessary vegetable oils and volatile thinners to produce elasticity, waterproofness, adherence, and durability in the finished paint film.

2.6.4. The red lead primer shall have satisfactory working properties, defined as follows:

The red lead primer shall be readily broken up with a paddle to a smooth, uniform paint suitable for brushing or spraying with the addition of not more than 10 per cent, by volume, of a suitable nontoxic thinner. The red lead primer applied by either method shall have good self-leveling properties, both of the vehicle and of the pigment, and, when brushed or sprayed on a vertical surface at a coverage rate of 500 sq ft per gallon, shall dry hard and elastic without running, streaking, or sagging. The drying properties shall be such that the primer film will dry dust free and free to touch in 1 hr, and dry to a smooth, hard film in 6 hr. The primer film produced shall have a flat or semigloss finish after 24-hr drying.

2.6.5. Red lead primer shall be packaged in iron pails of 5-gal maximum capacity.

Sec. 2.7—Synthetic White Enamel

When pipe to be erected aboveground is installed during hot weather, the second coat of primer shall be synthetic white enamel in place of synthetic red lead primer. Synthetic white enamel shall comply with the following:

2.7.1. The synthetic white enamel shall be a ready mixed paint composed of titanium oxide pigment and alkyd resin vehicle well ground together to produce a liquid coating which may be applied readily by brushing or spraying, which dries rapidly, and which provides a suitable bond with the synthetic red lead primer over which it is applied. The white enamel shall contain no benzol or other toxic solvent and shall have a minimum tendency to settle out the pigment in the container. The composition of the paint shall be as follows:

Pigment (100 per cent titanium oxide)—25 per cent.

Varnish vehicle (alkyd resin type)—75 per cent.

2.7.2. The vehicle shall be of the alkyd resin type and shall contain 40

per cent nonvolatile solids. The volatile constituents shall be 70 per cent coal-tar hydrocarbon solvents and 30 per cent high-flash naphtha.

2.7.3. The synthetic white enamel shall have satisfactory working properties, defined as follows:

The white enamel shall be readily broken up with a paddle to a smooth, uniform paint suitable for brushing or spraying with the addition of not more than 10 per cent, by volume, of a suitable nontoxic thinner. The white enamel as applied by either method shall have good self-leveling properties and, when brushed or sprayed on a vertical surface at a coverage rate of 500 sq ft per gallon, shall dry hard and elastic without running, streaking, or sagging. The drying properties shall be such that the paint film will dry dust free and free to touch in 1 hr, and dry to a smooth, hard film in 24 hr. The film when dried shall show a strong tendency to chalk on the surface when exposed to the weather.

Sec. 2.8—Aluminum Bronzing Liquid

2.8.1. The vehicle for aluminum paint shall be composed of treated oils, resins, metal driers, and volatile thinners. Treated oils shall be manufactured from the highest grade of spar varnish and linseed and chinawood oils. Resins employed shall be the so-called synthetic type, representing three distinct types, which shall perform the double duty of setting and drying the oil film through in the shortest possible time and increasing the resistance of the film to acids and alkalis and weathering. Solvents shall be a mixture of turpentine, coal-tar, and petroleum thinners designed to evaporate just rapidly enough to promote the proper speed of drying without impairing the working qualities of the vehicle and shall be of proper blend required to produce the maximum floating of the aluminum bronze.

2.8.2. The vehicle shall conform to the following tests:

(1) *Appearance.* Clear and transparent.

(2) *Color.* Not darker than Tube No. 14 of Gardner Color Standards for Varnishes and Lacquers.

(3) *Flash point.* Not below 86°F.

(4) *Nonvolatile matter.* Not less than 50 per cent by weight.

(5) *Viscosity at 77°F*—0.5–1.0 poises (Tubes A to D, Gardner-Holt Standards).

Test procedure is indicated in ASTM D154–53.

2.8.3. The vehicle shall have the following physical properties:

(1) Set to touch in not more than 3 hr at 70°F, 65 per cent relative humidity.

(2) Dry hard in not more than 24 hr at 70°F.

(3) When mixed with aluminum bronzing pigment in the ratio of 2 lb of pigment to 1 gal of vehicle, the resulting paint shall have good flowing, covering, and leveling properties, with the ability to float aluminum bronze flakes to the surface uniformly without allowing the bronze to break or separate before setting. The paint shall be readily applicable by air spray gun methods and, when applied to a vertical steel surface at the coverage rate of 300–400 sq ft per gallon, the paint film so applied shall dry without running, streaking, sagging, or wrinkling. The paint when dry shall have high light reflective properties.

Sec. 2.9—Aluminum Bronzing Pigment

The aluminum bronzing pigment shall conform to one of the following

Federal Specifications for the respective grades designated:

2.9.1. Standard Varnish Grade Powder—Federal Specifications TT-A-468a, Type I.

2.9.2. Standard Paste—Federal Specifications TT-A-468a, Type II.

Sec. 2.10—Cold-applied Coal-Tar Coating

The cold-applied coal-tar coating to be used for the first exterior coat on steel structures erected aboveground and exposed to more severe corrosive conditions shall comply with the following:

The cold-applied coal-tar coating shall be composed of a specially processed coal-tar pitch blended with selected solvents to a heavy consistency. No asphalt of either petroleum or natural base shall be acceptable as part of the ingredients. This coating shall conform to AWWA Specifications D102, Sec. 5.4.5.

Sec. 2.11—Cold-applied Coal-Tar Emulsion

The cold-applied coal-tar emulsion to be used for the second exterior coat on steel structures erected aboveground and exposed to more severe corrosive conditions shall comply with the following:

This thick, heavy-duty, cold-applied coal-tar emulsion shall be composed of a base derived from coal tar and inert mineral filler dispersed in water to produce a stable colloidal suspension. No asphalt of either petroleum or natural base shall be acceptable as part of the ingredients. The emulsion shall conform to Federal Specifications MIL-C-15203-A.

Section 3—Shop Application of Coal-Tar Primers and Enamels

Sec. 3.1—General

The contractor shall furnish all labor, equipment, and material required, shall prepare all surfaces to be coated, and shall apply the coal-tar primer and coal-tar enamel to all interior and exterior surfaces to be coated.

Sec. 3.2—Preparation of Surfaces

3.2.1. Before blasting, all oil and grease on the surfaces of the metal shall be removed thoroughly by flushing and wiping, using "Xylol," or other suitable coal-tar base solvents, and clean rags. The use of dirty or oily rags or solvent will not be permitted. All other foreign matter not removable by blasting shall be removed by suitable means. All metal surfaces shall be thoroughly cleaned by blasting. Blasted surfaces that rust before a priming coat has been applied shall be cleaned of all rust by buffing or wire-brushing or, at the discretion of the engineer, shall be reblasted. Adequate air separators shall be used to remove effectively all oil and free moisture from the air-supply to the blaster.

3.2.2. After cleaning, the pipe shall be protected from and maintained free of all oil, grease, and dirt that might fall upon the pipe from whatever source until it has received its final enamel coat. Any pipe showing pits after beginning of blasting shall be set aside immediately, pending examination by the engineer for approval, reconditioning, or rejection.

Sec. 3.3—Coal-Tar Priming

The coal-tar primer shall be as specified in the paragraphs under Sec. 2.1 of

these specifications, and the application shall be as follows:

3.3.1. All blasted steel surfaces shall be cleaned of dust and grit and shall be *primed immediately following blasting and cleaning.* The surfaces shall be dry at the time the coal-tar primer is applied, and no primer shall be applied during rain or fog unless protected from the weather by suitable housing.

3.3.2. At the option of the contractor, the application of the primer shall be by hand brushing, air gun spraying, or spraying-and-brushing, and shall be in accordance with instructions for application as supplied by the manufacturer of the primer. The apparatus to be used for application of the primer shall be approved by the engineer. Spray gun apparatus to be used shall include a mechanically agitated pressure pot and an air separator that will remove all oil and free moisture from the air supply.

3.3.3. The use of coal-tar primer that becomes fouled with foreign substances or has thickened through evaporation of the solvent oils will not be permitted.

3.3.4. After application, the coal-tar priming coat shall be uniform and free from floods, runs, sags, drips, holidays, or bare spots. Any bare spots or holidays shall be recoated with an additional application of primer. All runs, sags, floods, or drips shall be removed by scraping and cleaning and the cleaned area retouched, or, at the discretion of the engineer, all such defects shall be remedied by reblasting and repriming. Suitable measures shall be taken to protect wet primer from contact with rain, fog, mist, spray, dust, or other foreign matter until completely hardened and enamel applied.

3.3.5. In cold weather when the temperature of the steel is below 45°F, or at any time when moisture collects on the steel, the steel shall be warmed to a temperature of approximately 85°–100°F for sufficient time to dry the pipe prior to priming. To facilitate spraying and spreading, the primer may be heated and maintained during the application at a temperature of not more than 120°F.

3.3.6. The minimum and maximum allowable drying time of the coal-tar primer between application of primer and application of coal-tar enamel shall be in accordance with instructions issued by the manufacturer of the primer unless otherwise directed by the engineer. If the enamel is not applied within the maximum time after priming, as required by the manufacturer or as directed by the engineer, the pipe shall be reprimed with an additional light coat of primer, or, at the discretion of the engineer, the entire prime coat shall be removed by reblasting and the pipe reprimed.

Sec. 3.4—Preheating of Primed Pipe

3.4.1. At all times during cold weather when pipe temperature is below 45°F, or during rainy or foggy weather when moisture tends to collect on cold pipe, enameling shall be preceded by warming the pipe.

3.4.2. Warming shall be done by any method which will heat pipe uniformly to recommended temperature without injury to primer. Steel temperature of pipe shall not exceed 160°F.

3.4.3. After heating and while pipe is at its highest temperature, inside lining enamel shall be applied. Coating of the outside of the pipe with coal-tar enamel shall proceed immediately after the spinning operation is completed, while the pipe is still warm from preheating and centrifugal casting.

3.4.4. The same procedure shall apply for pipe primed on the outside with

synthetic red lead primer, except that the second coat of paint need not be applied while the pipe is warm.

Sec. 3.5—Coal-Tar Enamel Application

The type of coal-tar enamel to be used for the interior lining and the exterior coating shall be in accordance with Sec. 2.2 of these specifications. The application shall be as follows:

3.5.1. The enamel shall be heated in approved heating kettles equipped with accurate and easily read thermometers. In addition, the purchaser reserves the right to provide recording thermometers; such thermometers shall be installed on the heating kettles as directed by the engineer and at the expense of the contractor. Such thermometers will be checked and adjusted by the engineer whenever necessary. The charts therefrom shall constitute a basis for acceptance or rejection of any enamel because of improper heating and/or handling.

3.5.2. The operating and/or supply kettles shall be provided in sufficient numbers so that the enamel may be heated and coordinated with the application procedure. No enamel shall be held in the operation kettles at application temperatures for a longer period than recommended by the manufacturer or stated in his instructions. The enamel heated in supply kettles shall not exceed the temperatures and melting periods recommended by the coating manufacturer. Operating kettles shall not be used as a continuous source of supply by adding unmelted enamel during the time they are in use but shall be completely emptied of one charge and cleaned, if necessary, before the next charge of unmelted enamel is added; except when mechanically agitated kettles are used. In the practice of field patching, the engineer may permit continuous use of a heating kettle not exceeding 50-gal capacity. Kettles shall be covered with hinged lids which may be securely fastened down and shall be tightly closed during the heating and application of enamel except for neceessary loading and stirring.

3.5.3. The enamel shall be maintained moisture and dirt free at all times prior to, and at the time of, heating and application.

3.5.4. In loading the kettles, the enamel shall be broken into pieces suitable for the heating equipment used.

3.5.5. In heating the enamel, the charge shall be melted and brought up to application temperature as rapidly as possible without injury to the enamel. The temperature at which the enamel will be applied shall be in accordance with the recommendation furnished by the manufacturer. The hot enamel shall be thoroughly stirred at intervals not exceeding 15 min regardless of whether the enamel is being used from kettles or is being held ready for use. Iron paddles shall be used for stirring; wooden paddles will not be permitted.

3.5.6. The maximum allowable temperature to which enamel may be heated and the maximum allowable time that the enamel may be held in the kettles at application temperature shall be in accordance with the instructions supplied by the manufacturer.

3.5.7. Enamel that has been heated in excess of the maximum allowable temperature, or that has been held at application temperature for a period in excess of that specified, shall be condemned and rejected. Fluxing the enamel will not be permitted.

3.5.8. Excess enamel remaining in a kettle at the end of any heat shall not be included in a fresh batch in an amount greater than 10 per cent of the batch. Kettles shall be emptied and cleaned frequently as required. The material removed in cleaning the kettles shall be dumped and wasted.

Sec. 3.6—Application of Coal-Tar Enamel to Interior Surfaces

3.6.1. The primed steel surface to be enameled shall be dry and clean at the time the enamel is applied. No enamel shall be applied during cold weather, rain, or fog unless the pipe is preheated and/or protected by suitable housing.

3.6.2. The application of the enamel to the inside surface of all pipe other than specials shall be by centrifugal casting by either the Trough Method (Sec. 3.7 of these specifications) or the Retracting-Weir or Feed Line Method (Sec. 3.8 of these specifications).

3.6.3. During application of enamel, the pipe shall be revolved at the speed best suited to produce a smooth, glossy lining of uniform thickness. Finished coal-tar enamel lining shall be free from wrinkles, sags, blisters, or blowholes. Thickness of lining shall be $\frac{3}{32}$ in., and the allowable variations in thickness shall not exceed $\pm \frac{1}{32}$ in. All pieces of lined pipe in which excessive rough areas appear or other irregularities unsatisfactory to the engineer exist shall be stripped of the entire lining and relined as herein required for original lining.

3.6.4. All kettles shall be equipped with adequate screens to prevent particles of foreign matter or other deleterious materials from appearing in the finished coating.

3.6.5. Water used for chilling the enamel lining following centrifugal casting shall not be applied until the enamel has hardened sufficiently to prevent water marks.

Sec. 3.7—Centrifugal Casting of Coal-Tar Enamel by the Trough Method

3.7.1. Pipe shall be rotated on rubber-tired or steel wheels with suitable guards to prevent the pipe from leaving the rolls during spinning operations.

3.7.2. Molten enamel shall be introduced into the pipe by a pouring trough extending the full length of the pipe in either one or two sections. The pouring trough shall be level and shall have a straight and even pouring lip. The trough may be heated either by electrical heating elements or by a gas flame to a temperature best adapted to the equipment available.

3.7.3. Transfer of molten enamel from kettles to pouring troughs shall be conducted in such a manner as to prevent excessive loss of heat. Hot enamel shall be held in the pouring troughs between filling and pouring for not more than 1 min. Enamel shall not be poured from troughs into the pipe until the pipe has reached its maximum speed of rotation.

3.7.4. Enamel shall be poured by inverting the trough with a uniform rotation and at such speed as to distribute the enamel evenly throughout the pipe.

3.7.5. Immediately after the pouring operations, the trough shall be righted and removed from the pipe and cleaned, when necessary, of all excess enamel remaining in the trough. Such enamel may be reused, if it is clean and free of dirt, by adding to fresh batches in quantities not exceeding 10 per cent of unmelted enamel.

Sec. 3.8—Centrifugal Casting of Coal-Tar Enamel by the Retracting-Weir or Feed Line Method

3.8.1. Pipe shall be rotated on rubber-tired wheels with suitable guards or holddown wheels to prevent the pipe from leaving the rolls during spinning operations.

3.8.2. The hot enamel shall be introduced into the rotating pipe by means of a retractable feed line or over a traveling weir whose pouring lip is parallel to the longitudinal axis of the pipe. In either case, the discharge element of the supply mechanism shall travel the entire length of the pipe. The speed of travel shall be properly coordinated with the speed of rotation to insure complete multiple application of the molten enamel.

3.8.3. Molten enamel shall be supplied to the weir or feed line from a reservoir through supply pipes and maintained at application temperature by means of insulation and by the use of suitable methods of heating both reservoir and supply line. Supply of enamel shall be by means of a power-driven circulation pump.

Sec. 3.9—Application of Coal-Tar Enamel to Exterior Surfaces

3.9.1. The primed steel surface to be enameled shall be dry and clean at the time the enamel is applied. Any damage occurring to the primer coat shall be repaired by retouching before application of the enamel.

3.9.2. External enamel shall be applied by pouring on the revolving pipe and spreading to the specified thickness. Enamel shall be applied so that each spiral resulting from the spreading operations shall overlap the preceding spiral, producing a continuous coat free from defects. The thickness of coating shall be $\frac{3}{32}$ in., and the allowable variation in thickness shall not exceed $\pm \frac{1}{32}$ in.

3.9.3. The enameled pipe shall not be rolled or supported on its enameled surface until thoroughly cooled and hardened.

3.9.4. For application to specials and other shapes, see Sec. 3.11 of these specifications.

Sec. 3.10—Application of Coal-Tar Enamel at End of Pipe Sections

3.10.1. When pipe sections are to be joined together by field welding or riveting, the protective materials shall be left off the inside and outside surfaces at the ends a distance sufficient to permit the making of field joints without injury to the lining and coating.

3.10.2. When pipe sections are to be joined together with mechanical couplings, the enamel shall be left off the exterior of the pipe a distance back from the ends of 1 in. more than one-half the overall length of the assembled coupling. The interior enamel lining shall extend to the pipe end.

3.10.3. For joints other than specified herein, the length of pipe to be left bare at ends shall be in accordance with instructions supplied by the engineer.

Sec. 3.11—Specials—Cleaning, Lining, and Coating

The results of cleaning, lining, and coating of specials shall be equivalent to the results of similar work on straight pipe sections. Methods deviating from the prescribed procedure shall require approval by the engineer. If the shape precludes spinning, the lining and exterior coating shall be applied by hand daubers as follows:

3.11.1. All surfaces shall be double coated by applying the enamel with hand daubers. The brush strokes of

enamel shall be made in the direction of flow. All brush strokes shall overlap and form a continuous coating. The daubing may be done by the double-lap or "shingling" method. The work shall be done in a workmanlike manner, and no indiscriminate smearing of the enamel will be permitted. On all welds the strokes of the first coat of enamel shall be applied along the weld.

3.11.2. Enameling buckets shall be filled from the heating kettles with ladles or from spigots attached to the kettles and shall not be dipped for filling. Buckets shall be kept clean and free of dirt at all times and shall not be set directly upon the ground or on enameled surfaces but shall be set upon suitable pads or blocks. Buckets shall not be allowed to accumulate excess chilled enamel but shall be kept clean.

3.11.3. Enamel shall not be used from the enameling buckets below the minimum temperature specified by the manufacturer.

3.11.4. All drips and splashes of enamel on primed surfaces shall be carefully scraped off before the hand-brushed coat of enamel is applied. This pertains particularly where overhead hand enameling is necessary inside of pipe or specials.

3.11.5. Hand-enameling daubers shall be of the size best adapted for the work and shall be subject to the approval of the engineer. Daubers shall be made of the best grade of Tampico Fiber set in solid hardwood handles. Mops, sweeps, or knot daubers shall not be used. Long hand horseshoe daubers will be acceptable for large areas and flat work.

Sec. 3.12—Fittings

All fittings such as manholes, service connections, air valves, and blowoff connections shall be protected with coal-tar primer and coal-tar enamel, and the same application procedure shall be employed as specified under Sec. 3.11 of these specifications.

Sec. 3.13—Electrical Inspection

The contractor shall conduct electrical inspection of all of the coating by means of an approved electrical flaw detector delivering approximately 8,000–10,000 v at low amperage. Before final shop acceptance of coal-tar enamel coating, the entire interior and exterior surfaces of all coated pipe shall be tested, and all defects found shall be satisfactorily repaired by and at the expense of the contractor.

Sec. 3.14—Use of Whitewash on Exterior

Outside surfaces of all pipe and specials shall be given a coat of water-resistant whitewash immediately following final inspection.

Section 4—Field Procedure and Enameling

Sec. 4.1—Transporting and Handling Enameled Pipe

4.1.1. Protected pipe at all times shall be handled with equipment such as stout, wide belt slings and wide padded skids designed to prevent damage to the coating. Bare cables, chains, hooks, metal bars, or narrow skids shall not be permitted to come in contact with the coating. All handling and hauling equipment shall be approved by the engineer before use.

4.1.2. When shipped by rail, all pipe shall be carefully loaded on properly padded saddles or bolsters. All bearing surfaces and loading stakes shall be

properly padded with approved padding materials. Pipe sections shall be separated so that they do not bear against each other, and the whole load must be securely fastened together to prevent movement in transit. When applicable to this type of pipe, the pipe shall be loaded and tied into a unit load in strict accordance with the current loading rules of the American Railway Association.

4.1.3. In truck shipments, the pipe shall be supported in wide cradles of suitably padded timbers hollowed out on the supporting surface to fit the curvature of pipe, and all chains, cables, or other equipment use for fastening the load shall be carefully padded. For smaller-diameter pipe, sand- or sawdust-filled bags may be used instead of hollowed-out timbers.

4.1.4. The purchaser shall inspect the pipe and pipe protection on cars or trucks at destination, and if the pipe or pipe protection is found damaged, claim shall be made against the carrier.

Sec. 4.2—Handling Enameled Pipe in Field or at Trench

4.2.1. Pipe shall be stored along the trench side, supported on wooden timbers placed under the uncoated ends to hold the pipe off the ground.

4.2.2. Pipe shall be hoisted from the trench side to the trench by means of a wide belt sling. Chains, cables, tongs, or other equipment likely to cause damage to the enamel coating will not be permitted, nor will dragging or skidding the pipe. The contractor shall allow inspection of the coating on the under side of the pipe while suspended from the sling. Any damage shall be repaired before lowering the pipe into the trench.

4.2.3. Where the trench traverses rocky ground or ground containing hard objects that would penetrate the protective coating, a layer of screened earth or sand not less than 3 in. in thickness shall be placed in the bottom of the trench prior to installation of pipe.

4.2.4. At all times during erection of the pipeline the contractor shall use every precaution to prevent damage to protective coating on the pipe. No metal tools or heavy objects shall be unnecessarily permitted to come in contact with the finished coating. Workmen will be permitted to walk upon the coating only when necessary, and in case of such necessity the workmen shall wear shoes with rubber or composition soles and heels. This shall apply to all surfaces, whether bare, primed, or enameled. Any damage to the pipe or the protective coating from any cause during the installation of the pipeline and before final acceptance by the purchaser shall be repaired as directed by the engineer, by and at the expense of the laying contractor.

Sec. 4.3—Welded Field Joints—Coal-Tar Enamel Lining and Coating

4.3.1. The coal-tar primer and coal-tar enamel used shall be the same material as used for coating and lining pipe.

4.3.2. *Interior.* Before field pressure testing, interior welds of field joints shall be cleaned. Primer shall then be applied and allowed to dry according to the coating manufacturer's instructions. Hot enamel shall next be applied with daubers to specified thickness and shall overlap the main body of coating on each side of the weld to form a continuous coating free from defects. For coating field joints, there shall be located at frequent intervals along the pipe pour holes through which hot enamel may be poured into enameling buckets inside the pipe. (The require-

ments of this paragraph are applicable only to those sizes of pipe—27 in. and larger—into which it is possible to enter for cleaning and applying primer and enamel.)

4.3.3. *Exterior.* After field pressure tests have been completed, joints shall be cleaned and primed. When the primer is dry, the field joints shall be manually coated to the specified thickness. Enamel shall overlap the coating on each side of the field joint to form a continuous external coating free from defects.

4.3.4. All hand enameling shall be done in accordance with the procedure outlined in paragraphs under Sec. 3.11 of these specifications, and heating of enamel for field application shall be done in accordance with the procedure outlined in paragraphs under Sec. 3.5 of these specifications.

4.3.5. All field coating work shall be thoroughly inspected by the contractor using an electrical flaw detector, and any flaws or holidays found shall be repaired by the contractor.

Sec. 4.4—Mechanical Couplings—Cleaning, Priming, and Coating

At the point of manufacture, all couplings shall be cleaned, then primed with the coal-tar primer specified by the manufacturer of the coating used on the pipe. The couplings and the exposed pipe ends shall be reprimed in the field. When the primer is dry, these surfaces shall be coated with the AWWA coal-tar enamel coating recommended by the manufacturer of the coating used on the pipe. The coating shall be capable of conforming to the normal movement of the buried pipe without cracking.

Sec. 4.5—Backfilling

Backfilling shall be conducted at all times in such a manner as to prevent damage and abrasion to coal-tar enamel exterior protection on pipe.

4.5.1. Placing of backfill about exterior-protected pipe shall be done only in the presence of the inspector after his final inspection and acceptance of exterior protection on the pipe.

4.5.2. Immediately after placing and aligning pipe in the trench and before completing the joint, loose backfill shall be placed about the pipe to a depth of about 6 in. above the pipe, except at field joints. This backfill shall consist only of fine soil, sand, or other selected backfill.

4.5.3. If rocks or other hard objects occur in the backfill along any section of the pipeline, such backfill shall be screened before being placed about the pipe, or, at the option of the contractor, suitable waste backfill from other parts of the line may be transported to and placed about the pipe in such sections.

4.5.4. Settlement of backfill in the trench shall be by means of flooding, puddling, tamping, or jetting. Rodding with metal rods will not be permitted.

Section 5—Application of Paint to Exposed Exterior Steel Surfaces Erected Aboveground

Sec. 5.1—General

Contractor shall furnish all labor, equipment, and materials required and shall prepare, paint, or coat all exposed steel surfaces erected aboveground.

5.1.1. For ordinary atmospheric conditions, the steel surfaces shall receive two coats of synthetic red lead primer (or one coat of synthetic red lead primer and one coat of synthetic white enamel) and one coat of aluminum paint.

5.1.2. For more corrosive than normal conditions, the steel surfaces shall receive one coat of heavy-bodied, cold-applied coal-tar coating, one coat of heavy-bodied coal-tar emulsion, and one coat of aluminum paint. This system may be applied either to bare metal or to plates and structurals which have been properly cleaned at the shop, then shop primed with one coat of coal-tar primer referred to in Sec. 2.1. Each coat of coal-tar coating and coal-tar emulsion shall be applied at the coverage rate of approximately 60 sq ft per gallon.

Sec. 5.2—Preparation of Exterior Surfaces of Pipe

Preparation of exterior surfaces shall comply in all respects with the procedure outlined in paragraphs under Sec. 3.2 of these specifications. After completion of field-welded joints, they shall be properly cleaned before field application of red lead primer or the cold-applied coal-tar coating.

Sec. 5.3—Priming of Exterior Surfaces of Pipe

5.3.1. Red lead primer to be used shall be as specified in paragraphs under Sec. 2.6 of these specifications. Application of red lead primer shall be as specified for coal-tar priming in Sec. 3.3.1–3.3.4, inclusive, of these specifications.

5.3.2. Coal-tar primer shall be applied to all shop-blasted surfaces which are to be coated in the field with cold-applied coal-tar coating and coal-tar emulsion. Coal-tar primer to be used shall be as specified in paragraphs under Sec. 2.1 of these specifications. Application of coal-tar primer shall be as specified in paragraphs under Sec. 3.3 of these specifications. The coal-tar primer shall not be applied to surfaces which are to be blasted in the field after erection.

5.3.3. Care shall be taken to prevent abrasion or scarring of the primed surfaces before the film has dried hard and firm. Any damage to red lead or coal-tar primer shall be repaired before subsequent coats are applied. Red lead primer shall be allowed at least 24 hr drying time before a second coat of red lead primer or white enamel is applied.

Sec. 5.4—Second Coating of Exterior Surfaces of Pipe

Material and application for the second coat of red lead primer or white enamel shall comply in all respects with these specifications.

Sec. 5.5—Finish Coat of Aluminum Paint on Exterior Steel Surfaces

5.5.1. Finish coat shall be aluminum paint applied in the field by air spray gun in one or two coats as specified by the purchaser.

5.5.2. Aluminum paint shall be composed of aluminum vehicle and aluminum bronzing pigment in accordance with these specifications. Aluminum

paint shall be mixed in the field as required for the work in a ratio of 2 lb of pigment to 1 gal of vehicle. No additional thinner shall be used in the paint.

5.5.3. Before application of finish coat of aluminum paint, the field joints shall be cleaned of all dirt and rust and primed and recoated with the same material in the same manner as prescribed for shop priming of the pipe.

Sec. 5.6—First Coat of Cold-applied Coal-Tar Coating

5.6.1. Cold-applied coal-tar coating to be used shall be as specified in paragraphs under Sec. 2.10 of these specifications. This cold-applied coal-tar coating shall not be applied to the inside surfaces of the pipe because it may impart a taste to potable water. It can be applied by brushing or spraying. Special equipment is required for satisfactory spray application. It shall be applied at the coverage rate of approximately 60 sq ft per gallon. This cold-applied coal-tar coating must be applied either to bare metal or to plates and structurals which have been properly cleaned at the shop, then shop primed with one coat of coal-tar primer referred to in Sec. 2.1. This coating shall not be applied to surfaces previously painted with red lead primer. The surfaces shall be dry at the time the coal-tar coating is applied, and no coating shall be applied during rain or fog.

5.6.2. The cold-applied coal-tar coating applied in the field shall be allowed at least 24 hr drying time before the coat of coal-tar emulsion is applied.

Sec. 5.7—Application of Cold-applied Coal-Tar Emulsion

5.7.1. Cold-applied coal-tar emulsion to be used shall be as specified in paragraphs under Sec. 2.11 of these specifications. This emulsion shall not be applied to the interior surfaces of the pipe. It may be applied by brushing or spraying. Special equipment is required for satisfactory spray application. It shall be applied at the rate of approximately 60 sq ft per gallon. This cold-applied coal-tar emulsion shall be applied over the cold-applied coal-tar coating, after that coat has become dry. No emulsion shall be applied during rain or fog.

5.7.2. Containers of the cold-applied coal-tar emulsion shall be kept at temperatures above 32°F to prevent freezing.

APPENDIX

Section A1—General

Sec. A1.1—Scope

This Appendix covers material specifications and application procedures for additional exterior protection required as follows:

A1.1.1. *For the outside of all pipe less than 30 in. in diameter to be placed underground,* a coat of coal-tar primer followed by a hot coat of coal-tar enamel into which shall be bonded a single layer of asbestos felt wrap, and finished with one coat of water-resistant whitewash or a single wrap of kraft paper, as outlined in Sec. A1.2.

A1.1.2. *For the outside of all pipe, regardless of diameter, to be placed underground,* under unusual construction conditions, a coat and wrap system best suited to the conditions outlined in one of the sections A1.2, A1.3, A1.4, or A1.5 in this Appendix.

A.1.1.3. These additional exterior protective measures, for pipe to be installed under unusual construction con-

ditions, are not a part of the specifications unless specifically included by the purchaser as provided in Sec. 1.3 of the main specifications.

Sec. A1.2—Bonded Asbestos Felt Wrap

A1.2.1. This type of additional exterior protection shall be used on all pipe less than 30 in. in diameter to be placed underground; or when the engineer desires a single wrap on pipe 30 in. in diameter and larger to provide additional exterior protection because of soil stresses.

A1.2.2. The pipe shall be lined on the inside and coated on the outside with coal-tar enamel in accordance with all provisions of the specifications, and the enamel used on the outside shall be applied to a thickness of $\frac{3}{32}$ in. with an allowable variation of $\pm \frac{1}{32}$ in. under the asbestos felt.

A1.2.3. Asbestos felt shall conform to the material specified in Sec. A2.1 of this Appendix.

A1.2.4. Application of the asbestos felt shall conform to the procedure specified in Sec. A3.1 of this Appendix.

A1.2.5. Final pipe protection shall be whitewashed as provided in the specifications or wrapped with kraft paper specified in Sec. A2.2 of this Appendix.

Sec. A1.3—Coal-Tar Enamel and Bonded Double Asbestos Felt Wraps

A1.3.1. This type of additional exterior protection shall be used only where extraordinarily severe soil conditions exist, or on submarine lines, river crossings, etc.

A1.3.2. The pipe shall be lined on the inside and coated on the outside with coal-tar enamel in accordance with all provisions of the specifications, and the enamel used on the outside shall be applied to a thickness of $\frac{3}{32}$ in. with an allowable variation of $\pm \frac{1}{32}$ in. under the first bonded wrap of asbestos felt, and $\frac{1}{32}$-in. minimum thickness under the second bonded wrap of asbestos felt.

A1.3.3. Asbestos felt shall conform to the material specified in Sec. A2.1 of this Appendix.

A1.3.4. Application of the asbestos felt shall conform to the procedure specified in Sec. A3.1 of this Appendix.

A1.3.5. Final pipe protection shall be whitewashed as provided in the specifications or wrapped with kraft paper specified in Sec. A2.2 of this Appendix.

A1.3.6. The resultant construction of this exterior protection shall be:

(1) Coal-tar primer.
(2) Coal-tar enamel ($\frac{3}{32}$ in., $\pm \frac{1}{32}$ in., thick).
(3) Bonded asbestos felt.
(4) Coal-tar enamel ($\frac{1}{32}$ in. minimum).
(5) Bonded asbestos felt.
(6) Whitewash (or kraft paper).

Sec. A1.4—Coal-Tar Enamel, Fibrous Glass Mat, and Bonded Asbestos Felt Wrap

A1.4.1. This type of additional exterior protection shall be used only where extraordinary soil conditions exist, or on submarine lines, river crossings, etc.

A1.4.2. The pipe shall be lined on the inside and coated on the outside with coal-tar enamel in accordance with all provisions of the specifications, except that the fibrous glass mat shall be embedded in the outside of the enamel applied to a thickness of $\frac{3}{32}$ in. with an allowable variation of $\pm \frac{1}{32}$ in.; and there shall be a $\frac{1}{32}$-in. minimum thickness of enamel under the bonded wrap of asbestos felt.

A1.4.3. Fibrous glass mat shall conform to the material specified in Sec. A2.3 of this Appendix.

A1.4.4. Asbestos felt shall conform to the material specified in Sec. A2.1 of this Appendix.

A1.4.5 Application of fibrous glass mat shall conform to the procedures specified in Sec. A3.2 of this Appendix.

A1.4.6. Application of the asbestos felt shall conform to the procedures specified in Sec. A3.1 of this Appendix.

A1.4.7. Final pipe protection shall be whitewashed as provided in the specifications or wrapped with kraft paper specified in Sec. A.2.2 of this Appendix.

A1.4.8. The resultant construction of this exterior protection shall be:

(1) Coal-tar primer.

(2) Coal-tar enamel ($\frac{3}{32}$ in., $\pm \frac{1}{32}$ in., thick).

(3) Fibrous glass mat.

(4) Coal-tar enamel ($\frac{1}{32}$ in. minimum).

(5) Bonded asbestos felt.

(6) Whitewash (or kraft paper).

Sec. A1.5—Sand Shield

A1.5.1. This type of exterior protection shall be used only when the methods of backfill as required in Sec. 4.5 of the specifications are not available or are considered undesirable.

A1.5.2. The pipe shall be lined inside and coated outside with coal-tar enamel in accordance with all provisions of the specifications. In addition, the entire pipeline, or such portions of the line as are designated by the purchaser, shall be completely surrounded by sand before any backfill is placed in the trench. A minimum depth of 3 in. of sand shall be placed in the trench before the pipe is laid, and the sand shall be placed about the pipe and to a minimum cover of 3 in. over the pipe.

Sec. A1.6—Reinforced Cement-Mortar Shield

When a reinforced cement-mortar shield is desired over the exterior coat of coal-tar enamel, the materials and application procedures shall conform to the applicable requirements of AWWA Specifications C205.

Section A2—Material Specifications

Sec. A2.1—Asbestos Coal-Tar Saturated Felt

The wrapper shall be composed of an asbestos felt having an asbestos content of not less than 85 per cent of the desaturated felt with suitable binder, the whole saturated with a distilled coal-tar to produce the following characteristics in the finished felt:

A2.1.1. *Appearance.* The finished tar-saturated asbestos felt shall have a calendered surface free from visible external defects. When unrolled at temperatures of 32°–100°F, it shall not stick to such an extent as to cause tearing.

A2.1.2. *Weight per 100 sq ft.* Exclusive of all conmminuted surfacing or sand which has been added to prevent sticking in the rolls, the weight shall be not less than 12 lb nor more than 15 lb per 100 sq ft.

Test method. ASTM D146–47, Sec. 1–9.

A2.1.3. *Breaking strength.* Average after test samples from the inside of the roll have been aged in free air for 72 hr:

(1) With fiber grain (longitudinal), not less than 25 lb.

(2) Across fiber grain (transverse), not less than 10 lb.

Test method. ASTM D146–47, Sec. 12(a).

A2.1.4. *Pliability.* Average after test samples from the inside of the roll have been aged in free air for 72 hr: No cracking of felt when bent over a 1-in. mandrel at 77°F.

Test method. With the trimmer described in Sec. 12(a) of ASTM D146–47, five 6-in. strips shall be cut with the fiber grain as shown at D-1 to D-5 (Fig. 1 of the ASTM specification) and immersed in water at 77°F (25°C) for 10–15 min. These strips shall be bent through 180 deg at a uniform speed, in exactly 2 sec, around a mandrel with a diameter of 1 in.

A2.1.5. *Saturation.* Average after test samples from the inside of the roll have been aged in free air for 72 hr: The saturation by extraction shall be not less than 22 per cent nor more than 32 per cent of the weight of the extracted felt.

Test method. ASTM D146–47, Sec. 16, omitting correction for entrained carbonaceous materials, calculated as follows:

$$\frac{\text{wt. of extracted saturant} \times 100}{\text{wt. of extracted felt (as defined)}} = \% \text{ saturation}$$

A2.1.6. *Loss on heating.* The loss on heating shall be not more than 10 per cent according to the following test method:

Test method. Cut two samples, 6 in. wide by 12 in. long, of saturated felt, weighing each strip, and suspend by wire hooks for 2 hr in an oven maintained at 200°F, ± 5°F. Care shall be taken to see that the felt does not touch the oven side or other samples of felt and that localized overheating of the samples does not take place. Remove from the oven, cool in a desiccator, and weigh. Compute the percentage of loss in weight based upon the original weight of the sample, minus the weight of surfacing. The average of the result on the two samples shall be reported as the loss on heating.

Sec. A2.2—Kraft Paper

The kraft paper shall be an 80-lb, 100 per cent sulfate, smooth. It may be imprinted at intervals with the name of the applicator or steel pipe manufacturer.

Sec. A2.3—Fibrous Glass Mat

A2.3.1. The fibrous glass mat shall be a thin, flexible, uniform mat, composed of glass fibers in an open porous structure, bonded together with a thermosetting resin which shall be compatible with the hot coal-tar enamel.

A2.3.2. No disbonding of individual glass fibers during or following the embedding process shall occur.

A2.3.3. The fibrous glass mat shall not cause bubbling under the conditions of application.

A2.3.4. The mat shall be sufficiently porous so that it can be embedded in the hot coal-tar enamel as it is applied to the exterior of the pipe.

A2.3.5. The mat shall be approximately 18 mils in thickness.

Section A3—Application Procedure

Sec. A3.1—Application of Asbestos Coal-Tar Saturated Felt

Asbestos felt shall be mechanically applied in a continuous end-feed machine or in a lathe-type machine or by approved field felt application equipment.

A3.1.1. External enamel and asbestos felt wrapper shall be applied to the revolving pipe so as to produce a coal-tar enamel coating to a thickness of $\frac{3}{32}$ in., and the allowable variation in the enamel thickness shall not exceed $\pm \frac{1}{32}$ in. The asbestos felt shall be definitely and positively bonded to the enamel. The enamel coating shall be continuous and free from defects, skips, or holidays.

A3.1.2. The asbestos felt as specified in Sec. A2.1 shall be of suitable width for smooth, spiral application and shall be of approximately uniform width. The lap of the felt shall be not less than $\frac{1}{2}$ in. The asbestos felt shall be applied neatly and smoothly and shall be free of wrinkles and buckles.

A3.1.3. Over the bonded asbestos felt wrapper shall be applied a spiral wrapping of kraft paper as specified in Sec. A2.2, unless outside surfaces are to be coated with whitewash following final inspection as specified in Sec. 3.14 of the main specification.

Sec. A3.2—Application of Fibrous Glass Mat

Fibrous glass mat shall be mechanically applied in a continuous end-feed machine or in a lathe-type machine or by approved felt application equipment.

A3.2.1. The fibrous glass mat shall be applied simultaneously with the first coat of coal-tar enamel. Sufficient tension shall be applied to the roll of fibrous glass mat to embed it in the enamel before the enamel sets or cools. The fibrous glass mat shall not be pulled through the hot enamel to the metal surface.

A3.2.2. The fibrous glass mat as specified in Sec. A2.3 shall be of suitable width for smooth, spiral application and shall be of approximately uniform width. The lap of the fibrous glass mat shall not be less than $\frac{1}{2}$ in.

A3.2.3. The second coat of hot coal-tar enamel shall be applied over the fibrous glass mat simultaneously with a single bonded wrap of asbestos coal-tar saturated felt.

A3.2.4. Fibrous glass mat shall not be used when two wraps of asbestos coal-tar saturated felt are applied in accordance with Sec. A1.3 of this Appendix.

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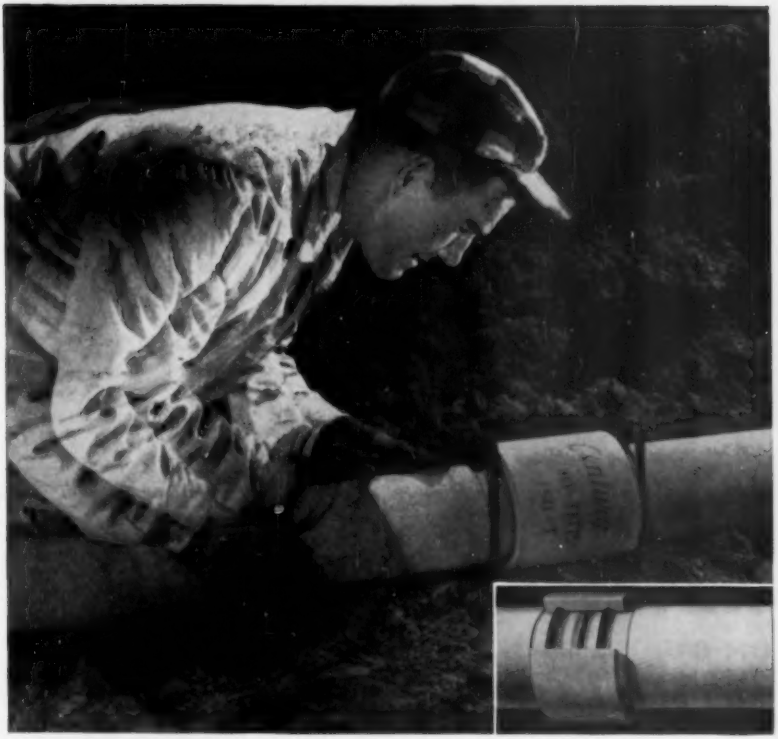

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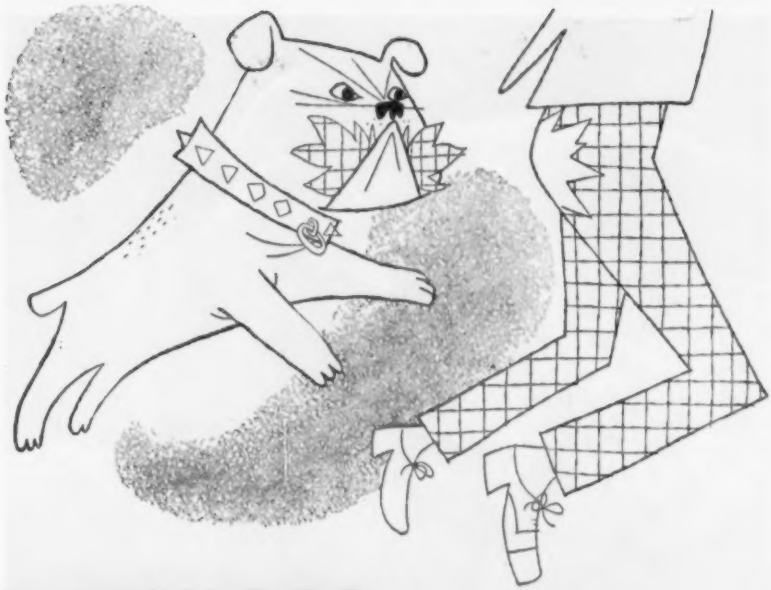

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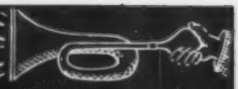

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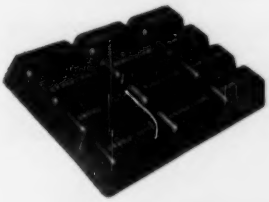

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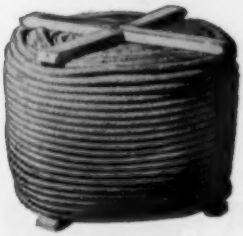

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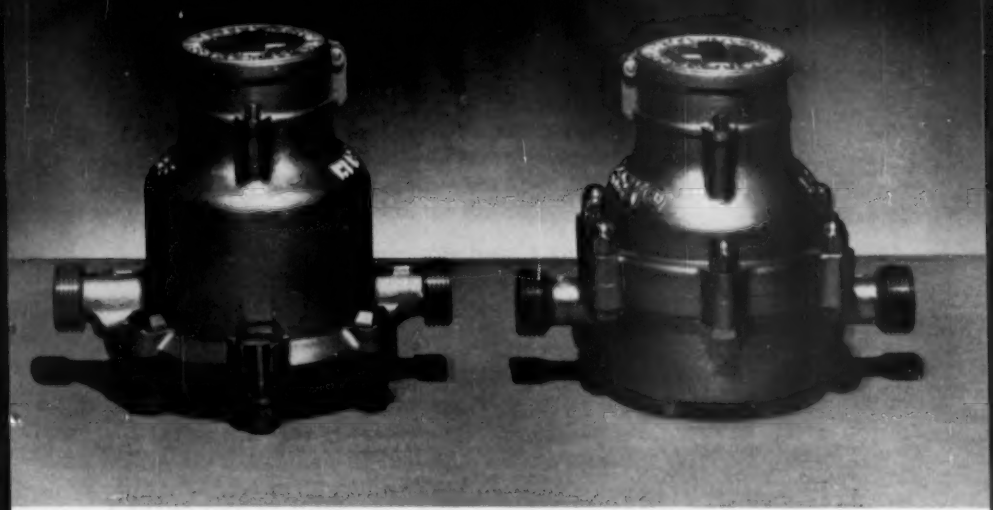

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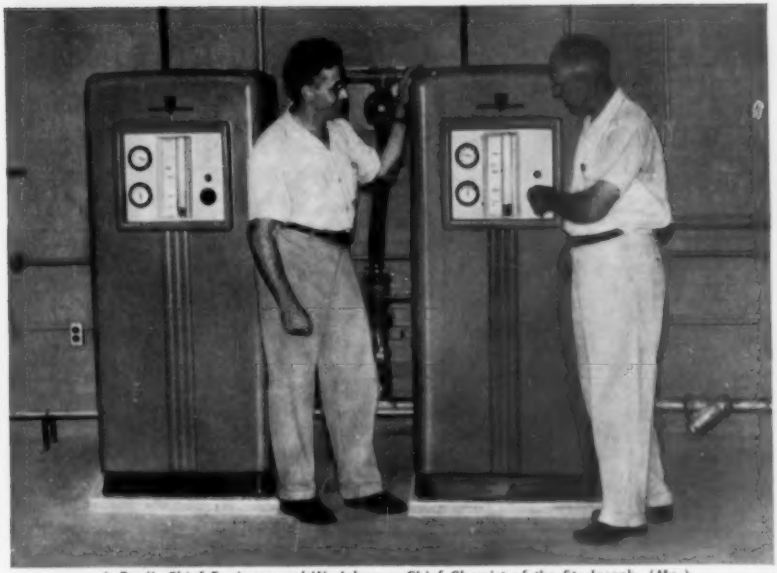

J. Pauli, Chief Engineer and W. Johnson, Chief Chemist of the St. Joseph, (Mo.) Water Company, discuss operation of their W&T V-notch chlorinators. The St. Joseph Water Co. is part of the American Water Works Service Co., Inc. system.

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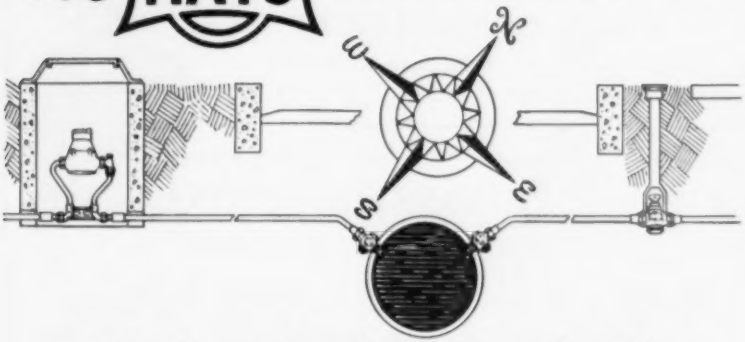

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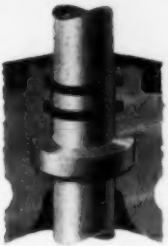

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Fig. 571

Fig. 561

Fig. 566

Fig. 566G

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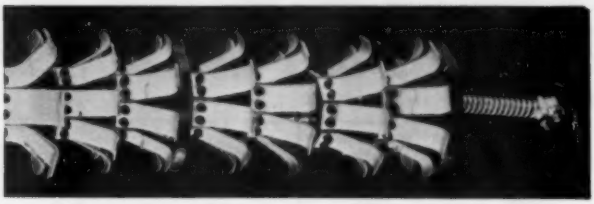

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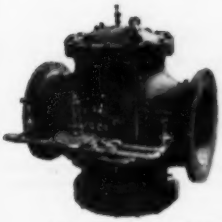

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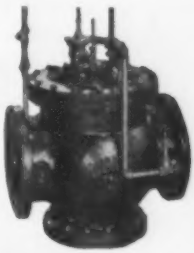

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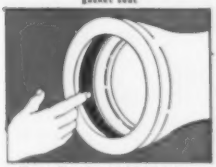
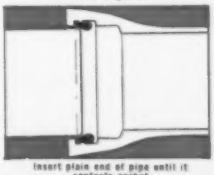
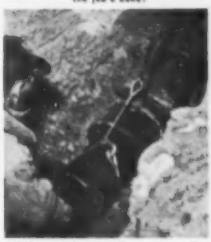


Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket

Force plain end to bottom of socket... the job's done!



8" Tyton Joint pipe for water main addition in Colorado.

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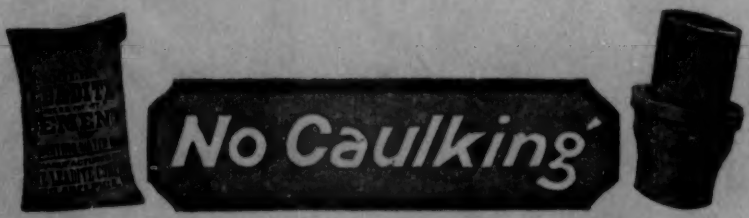
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